

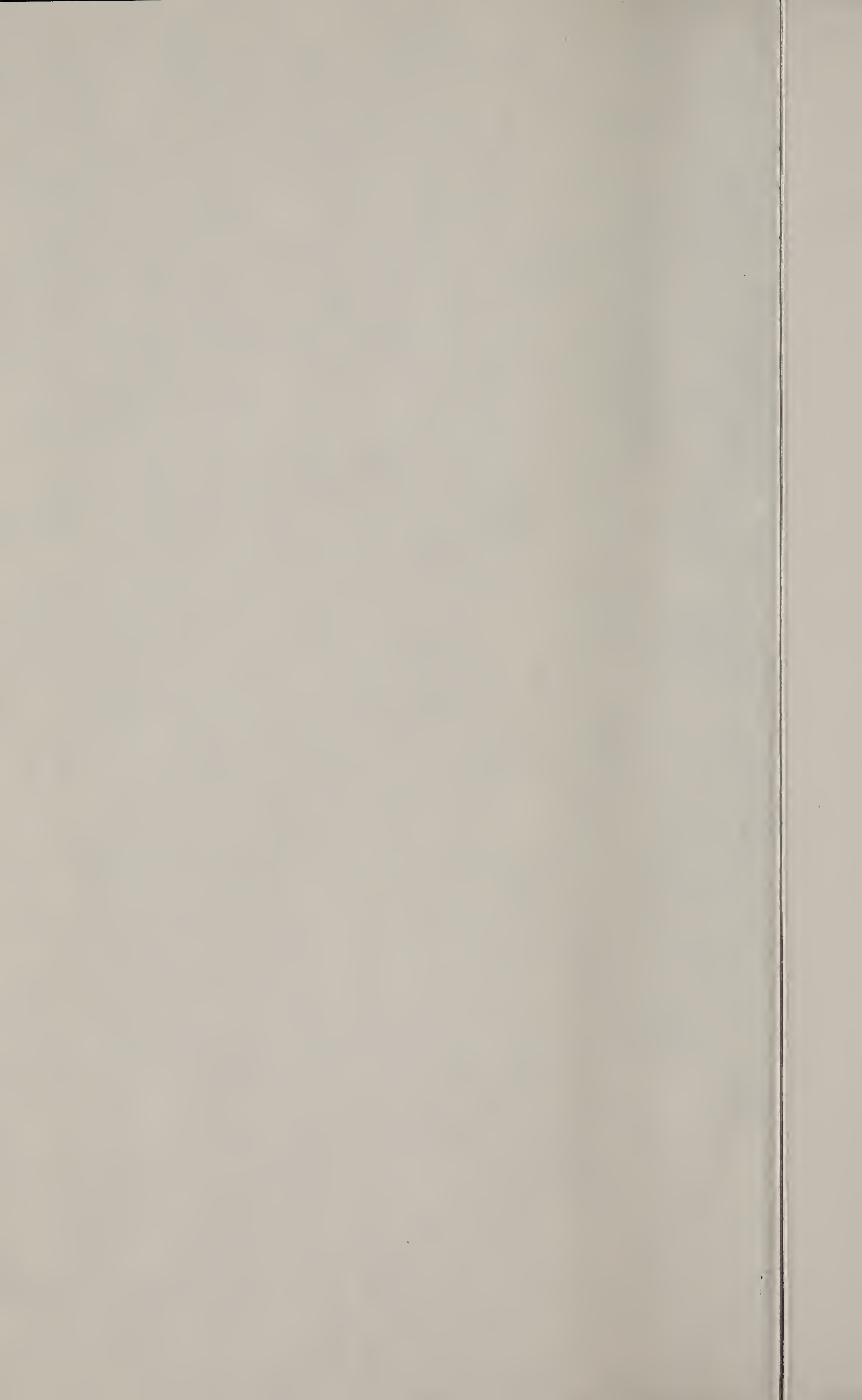
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PROCEEDINGS

of the

Nova Scotian Institute of Science

HALIFAX, NOVA SCOTIA

VOLUME 29

1979

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1979

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THE NOVA SCOTIAN INSTITUTE OF SCIENCE

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La Revue *Proceedings of the Nova Scotian Institute of Science* publie les travaux de l'Institut, des articles originaux et des notes avant trait aux sciences naturelles aux Provinces atlantiques, surtout dans les domaines de la biologie et de la géologie. Les manuscrits peuvent être en anglais ou en français, et seront soumis à l'avis d'experts avant d'être acceptés.

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Nova Scotian Species of Hygrophorus

C.J. Bird and D.W. Grund





NOVA SCOTIAN SPECIES OF *HYGROPHORUS**

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and

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Fifty-three species and varieties of *Hygrophorus* occurring in Nova Scotia are described and illustrated. Techniques for their identification are discussed, and both technical and field keys are provided. Two species, *H. lignicola* and *H. macrosporus*, are described as new, and one species, *H. pustulatus*, is reported as a new record for the province. Nine species previously collected or reported from Nova Scotia are excluded on grounds of doubtful or incorrect identification. Complexes, or assemblages of intergrading minor variants, are recognized for *H. olivaceoalbus*, *H. puniceus*—*H. coccineus*, and *H. miniatus*—*H. cantharellus*.

Infrageneric classification is based on the recent comprehensive North American study of Hesler and Smith (1963) with two modifications: (1) a new section, *Lignicolohygrophorus*, is created to accommodate *H. lignicola*, a species peculiar in its lignicolous habitat and dimitic hyphae; (2) species with conic but nonviscid pilei are removed from Series *Conici* to a new series, *Marginati*, in Subsection *Hygrocybe*.

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Introduction

The genus *Hygrophorus* Fries in North America contains some 244 taxa as recognized by Hesler and Smith (1963). We have found 53 species and varieties in Nova Scotia, but it is certain that this paper does not contain all the entities here, as our intensive work on the genus goes back only to 1965.

Hygrophorus is a colorful genus with species that range from green to snowy white, gray, brown, brilliant yellow and scarlet. There are always various species to be found throughout the mushroom season. The first may be found in late June, followed by a regular procession of taxa until late autumn, when there is a flush of autumnal forms that lasts into the hard frosts of early winter.

Historically, the genus is based on the Friesian tribes *Limacium* and *Clitocybe* (in part) in *Systema Mycologicum* (Fries 1821), and later, Fries (1835) proposed the generic name *Hygrophorus*. This infrageneric classification was retained with minor orthographic changes in *Epicrisis Systematis Mycologici* (Fries 1838), wherein *Hygrophorus* included the three tribes, *Limacium*, *Hygrocybe* and *Camarophyllus*.

Kummer (1871) raised the *Epicrisis* tribes to generic rank, and this partitioning of the Friesian genus was widely accepted until quite recently. Subsequently to Kummer's work, further attempts have been made by various mycologists to segregate genera from *Hygrophorus* sensu Fries, but the discovery of additional taxa has supported the original concept of one large genus.

Most of the proposed changes occurred in the segregate genus *Hygrocybe* (Fr.) Kummer. Two early segregates were *Godfrinia* Maire, to accommodate *Hygrophorus conicus* (Maire 1902), and *Hydrophorus* (Batt.) Earle with *Hygrophorus coccineus* as the nomenclatural type (Earle 1909). Murrill (1916) validly published *Hydrocybe* (P. Karsten's misspelling of *Hygrocybe*) and retained *Hygrophorus* Fr. for only the *Limacium* group (sensu Kummer). Singer (1951) reestablished *Hygrocybe* (Fr.) Karst. for those species with parallel lamellar trama, and in 1958 separated *Humidicutis* for *Hygrophorus marginatus* and other brightly colored, clampless species (Singer, 1958). The next year, Herink (1959) created *Gliophorus* and *Neohygrocybe*, both of which Singer later recombined with *Hygrocybe* (Singer 1962).

Heim (1936) proposed *Bertrandia* for *Hygrocybe*-like agarics with latex and pseudocystidia. Singer (1951) included this genus in his survey of the Hygrophoraceae Roze, and Hesler and Smith (1963) acknowledged it as distinct from *Hygrophorus*.

Besides *Hygrocybe* and *Bertrandia*, Singer (1951) recognized 3 other genera of Hygrophoraceae: *Camarophyllus* (Fr.) Karst., for species with interwoven gill trama; *Hygrophorus* Fr. (following Murrill's example) for those with divergent lamellar trama; and *Neohygrophorus* Singer to accommodate *Hygrophorus angelesianus* Smith and Hesler, formerly in subgenus *Pseudohygrophorus* (Smith & Hesler 1942). Later, Singer (1955) also erected *Hygroaster* for species with ornamented spores.

Heim (1957) proposed *Hodophilus* for species with interwoven trama and greenish spore print, formerly *Aeruginospora* Höhnelt. Although Singer regarded the green spore color as an erroneous observation, he reinstated *Aeruginospora* for clampless species with interwoven trama and hymeniform cuticle, including *Hygrotrama* Singer (Singer 1962). Herink's (1959) division of *Hodophilus* Heim into *Camarophylloopsis* Herink and *Hodophilus* (Heim) Herink was not recognized by Hesler and Smith (1963).

Hesler and Smith (1963) reaffirmed their original position (Smith & Hesler 1939; 1942) by reducing all the genera except *Neohygrophorus* to sections or parts thereof within Subgenus *Hygrophorus*. *Neohygrophorus* resumed its status as Subgenus *Pseudohygrophorus*, and these two subgenera constituted the single genus *Hygrophorus* Fr. The foregoing and other changes within the genus are summarized diagrammatically in Figure 1.

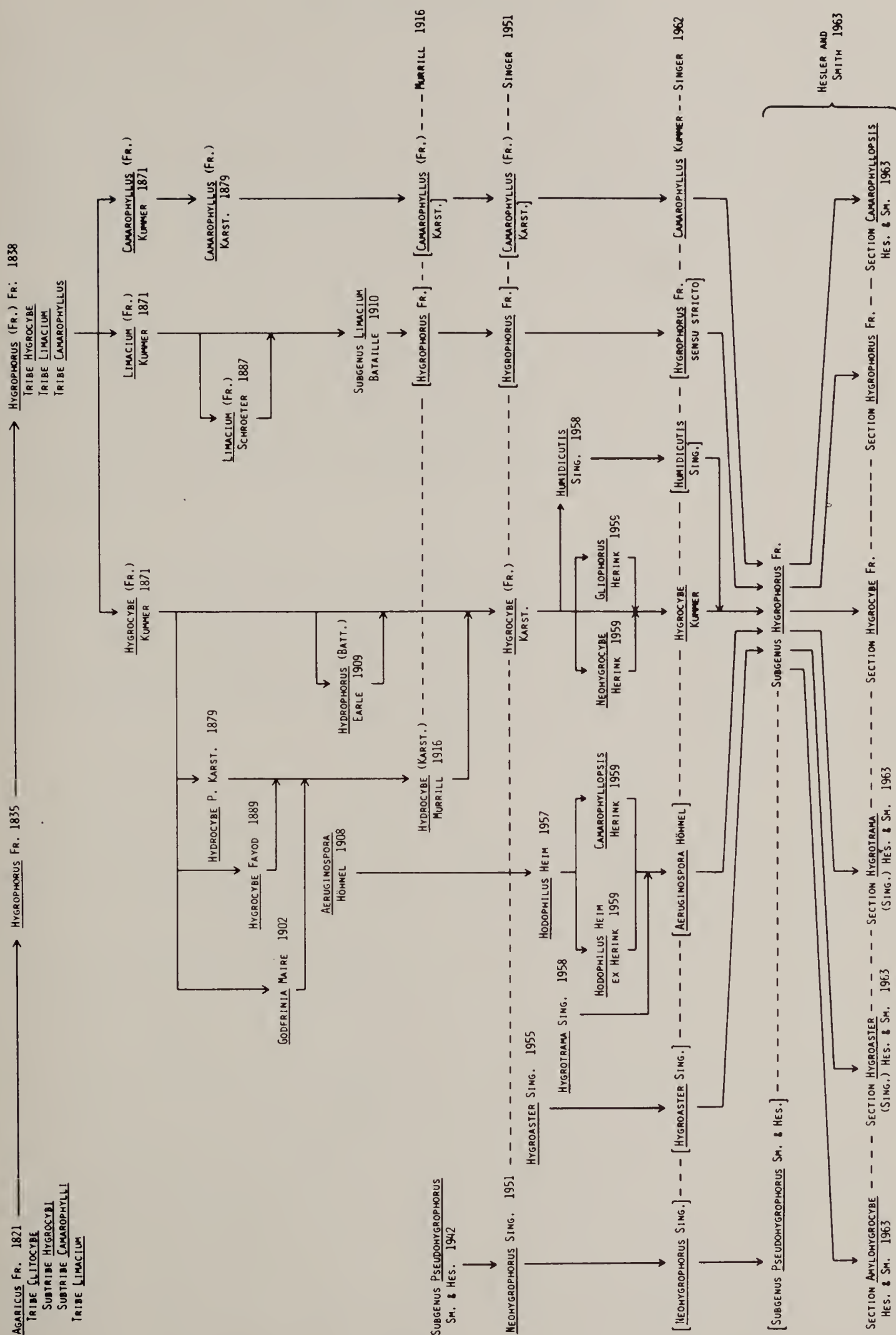


Fig 1. Flow diagram of the taxonomic history of *Hygrophorus*. All names are for genera unless designated otherwise. Brackets around names as used in several major publications indicate that the epithet and its author(s) had been established previously.

It is interesting that the Friesian tribes *Limacium*, *Hygrocybe* and *Camarophyllum* correspond so closely to the present sections *Hygrophorus*, *Hygrocybe* and *Camarophylloopsis*, respectively (Hesler & Smith 1963), as Fries knew nothing of the microscopic features now used to separate these groups. Beyond the addition of new species and the removal of several borderline taxa, *Limacium* and *Camarophyllum* are essentially unchanged. The most significant shift occurred when the Friesian species *Agaricus camarophyllum*, from which the generic name *Camarophyllum* was derived, was found to be a *Limacium* because of its divergent lamellar trama. Thus, *Camarophyllum* became unavailable at any infrageneric level for *Hygrophori* with interwoven trama (Donk 1949, apud Hesler & Smith 1963), and Hesler and Smith (1963) adopted the sectional name *Camarophylloopsis* instead.

Somers (1882) provided the earliest record of *Hygrophorus* (*H. eburneus* Fr.) for Nova Scotia, in the first published check list of fungi of the province. A series of similar lists published between 1882-1890 furnished only 1 additional species, *H. speciosus* Peck (Somers 1890). MacKay (1908) published a more comprehensive list, incorporating Somers' records and adding *H. conicus* Fr., *H. miniatus* Fr., and *H. chlorophanus* Fr. A supplementary list (MacKay 1913) reported *H. coccineus* Shaeff., *H. flavodiscus* Frost, *H. fuliginus* Frost, *H. pudorinus* Fr., and *H. puniceus* Fr., plus 2 species now regarded as questionable records (See *Doubtful and Excluded Species*, p. 12).

L. E. Wehmeyer, of the University of Michigan, collected in the Truro area between 1927-1935, and made brief excursions to Cape Breton Island, the Wolfville area, and Halifax County. In 1931 he was accompanied by A.H. Smith, then student assistant. Among the many collections that year were 15 taxa of *Hygrophorus*, and the new records for the province were *H. borealis* Pk., *H. ceraceus* Fr., *H. marginatus* Pk., *H. nitidus* B. & C., *H. peckii* Atk. [now *H. laetus* (Fr.) Fr.], *H. pratensis* Fr., *H. pratensis* var. *pallidus* Kauff. (now merged with the typical variety), *H. psittacinus* Fr. and *H. russula* (Fr.) Kauff. (Smith & Wehmeyer 1936).

K.A. Harrison, while a plant pathologist at the Canada Department of Agriculture Experimental Station, Kentville, N.S., made numerous collections of fleshy fungi, and Wehmeyer compiled these and other records of fungi for the Maritime provinces up to 1943 into 1 volume (Wehmeyer 1950). Harrison's duplicate collections from 1927-66 are now housed in the E.C. Smith Herbarium, Acadia University (ACAD), and include 35 species of *Hygrophorus* from Nova Scotia.

Bird and Grund (1970) supplied ten new records for the province, and described the new species, *H. murinus* Bird and Grund. Grund and Harrison (1974) described the new variety *H. conicus* (Fr.) Fr. var. *atrosanguineus* Grund and Harrison, and added 3 new records for the Maritime Provinces.

We have adopted the infrageneric classification proposed by Hesler and Smith (1963), with three modifications. (1) We omit sections, subsections, and series not found thus far in Nova Scotia. (2) We propose a new section, *Lignicolohygrophorus*, to accommodate a lignicolous species. (3) We create a new series, *Marginati*, which is segregated from Series *Conici* sensu Hesler and Smith (1963). In the latter system, Series *Conici* includes conic species with either viscid or dry pilei, and thus keys out under the 2 next higher taxa, Subsections *Hygrocybe* (dry) and *Punicei* (viscid). However, the similar conic series *Puri* is isolated in Subsection *Psittacini* because of stipe viscidness, although Hesler and Smith (1963, p. 216) acknowledge the close relationship of some of its species with the *H. conicus* group. It is not logical to combine Series *Conici* and *Puri*, regardless of viscidness of stipe or pileus, when the subsections have been delimited on that very basis. Nor does it seem reasonable to have 1 series bridging only 2 of the 3 subsections. Thus, we propose to remove conic species with nonviscid pilei and nonviscid stipes from Series *Conici* and assign them to a new series, *Marginati*, in Subsection *Hygrocybe*. As Series *Conici* thus now includes only species with viscid pilei (and dry stipes), we transfer it from Subsection *Hygrocybe* (Hesler & Smith, 1963) to Subsection *Punicei*.

Methods and Materials

Collection and Preservation

The specimens used in this investigation were carefully picked, wrapped in waxed paper, transported in baskets, and handled gently to minimize bruising. Notes were made of field habit and habitat, and, upon returning to the laboratory, spore prints and descriptions were prepared. Collections were assigned herbarium numbers and dried at 38-40°C. Later, they were relaxed in a steamer, lightly pressed, and redried for storage in 12.5 x 20-cm (5 x 8-in) envelopes under their given numbers in the E.C. Smith Herbarium, Acadia University, Wolfville, N.S. (ACAD).

Spore Prints

Spore prints were obtained by detaching the fresh pileus and placing it on pure white paper. When only one sporocarp was available, the stipe was placed through a hole in stiff, pure white paper and suspended thus over an open jar or beaker. Spore prints were made prior to storage of sporocarps in the refrigerator, as low temperatures inhibit discharge of spores.

Macrochemical Tests

Potassium hydroxide (KOH, 3% aqueous solution), ferrous sulphate (FeSO_4 , 10% aqueous solution), and Melzer's reagent [1.5 g. potassium iodide (KI) and 0.5 g iodine (I_2) in 20 ml water plus an equal volume of an aqueous solution (1:1 w:v) of chloral hydrate ($\text{CCl}_3\text{CH}(\text{OH})_2$)], were applied to fragments of the pileus, stipe, and lamellae. In *Hygrophorus*, the various tissues usually darken slightly or merely assume the color of the reagent; however, occasionally a significant color change occurs within 10 minutes. These reactions are discussed in the descriptions of the species.

Examination of Microscopic Structures

When possible, microscopic details were examined when sporocarps were fresh. Hyphae and basidia of dried specimens, when rehydrated in KOH solution, are brittle and frequently disintegrate in crush mounts. Moreover, hyphae occasionally fail to inflate fully when rehydrated and, in sections of pileal cuticle and lamellar trama, they sometimes do not resume their normal arrangement.

Unless otherwise stated, fresh material was mounted unstained in water, using standard 75 x 25-mm micro-slides and 22 x 22-mm cover glasses. Dried material was flooded with 100% ethanol and rehydrated in 3% KOH.

A. *Spores*. Measurements of spores were taken from spore deposits (prints) when available, to guarantee maturity (otherwise, a crush mount was made of a portion of lamella from a mature sporocarp). A deposit was applied to a film of Mayer's fixative on a micro-slide [Mayer's fixative: 50 ml egg white, 50 ml glycerine ($\text{C}_3\text{H}_5(\text{OH})_3$), and 1 g sodium benzoate ($\text{NaC}_7\text{H}_5\text{O}_2$); an aqueous solution of sodium benzoate (1:2 w:v) is added to the egg white]. At one end of the slide, a small drop of 3% KOH was placed over the spores, and at the other end a drop of Melzer's reagent to test for amyloidity.

B. *Hymenial Structures*. Crush mounts were used to examine basidia, cystidia, and spores in the absence of a spore print. A portion of lamella from a mature sporocarp was crushed beneath a cover glass, either in Melzer's reagent or in 3% KOH (or water) after staining with a 1:1 (v:v) mixture of 1% aqueous solutions of phloxine and Congo Red. Dried material was rehydrated and stained before crushing. With very few exceptions, as noted, camera lucida drawings for each taxon were prepared from a single crush mount.

C. *Lamellar Trama*. Lamellar trama was examined in free-hand transverse or

periclinal sections. Dried material was partially rehydrated in water and compressed for sectioning in elder pith. As *Hygrophorus* is usually very soft and fleshy, it was advantageous to dry the tissue to a leathery texture over an alcohol flame before sectioning; sections were mounted in 3% KOH.

The configuration of the lamellar trama is important at the level of section when keying species of *Hygrophorus*. There are 3 major types: interwoven, divergent and parallel (Figs 2-5). Parallel tramas may be subdivided into the *H. conicus* type, with broad, straight and sparingly septate hyphae (Fig 4); and the *H. coccineus* type, with inflated, subparallel and frequently septate hyphae (Fig 5). At times, the *H. coccineus* type approaches the interwoven type. Divergent tramas may have a thin, parallel mediostratum, but should not be confused with parallel trama in which the subhymenial hyphae diverge from a broad, parallel mediostratum. In sections prepared from dried material, divergent tramas may straighten (Hesler & Smith 1963), and interwoven trama may appear subparallel.

D. Pileal Cuticle. Pileal cuticle and context (trama) were examined in radial section. Unless the sporocarp had already been divided longitudinally, a narrow wedge wide enough to admit a razor blade was removed from the pileus. Sections were shaved from the exposed radial surface, passing the blade from cuticle to context to avoid tearing off gelatinous pellicles when present. Radial sections could also be taken directly from dry material, without prior rehydration, and mounted in 3% KOH. The depth of viscid cuticles, when present, was measured under low power (100x) without a cover glass. The weight of a cover glass tends to disrupt the arrangement of hyphae in gelatinous cuticles, and exaggerates the thickness of such layers.

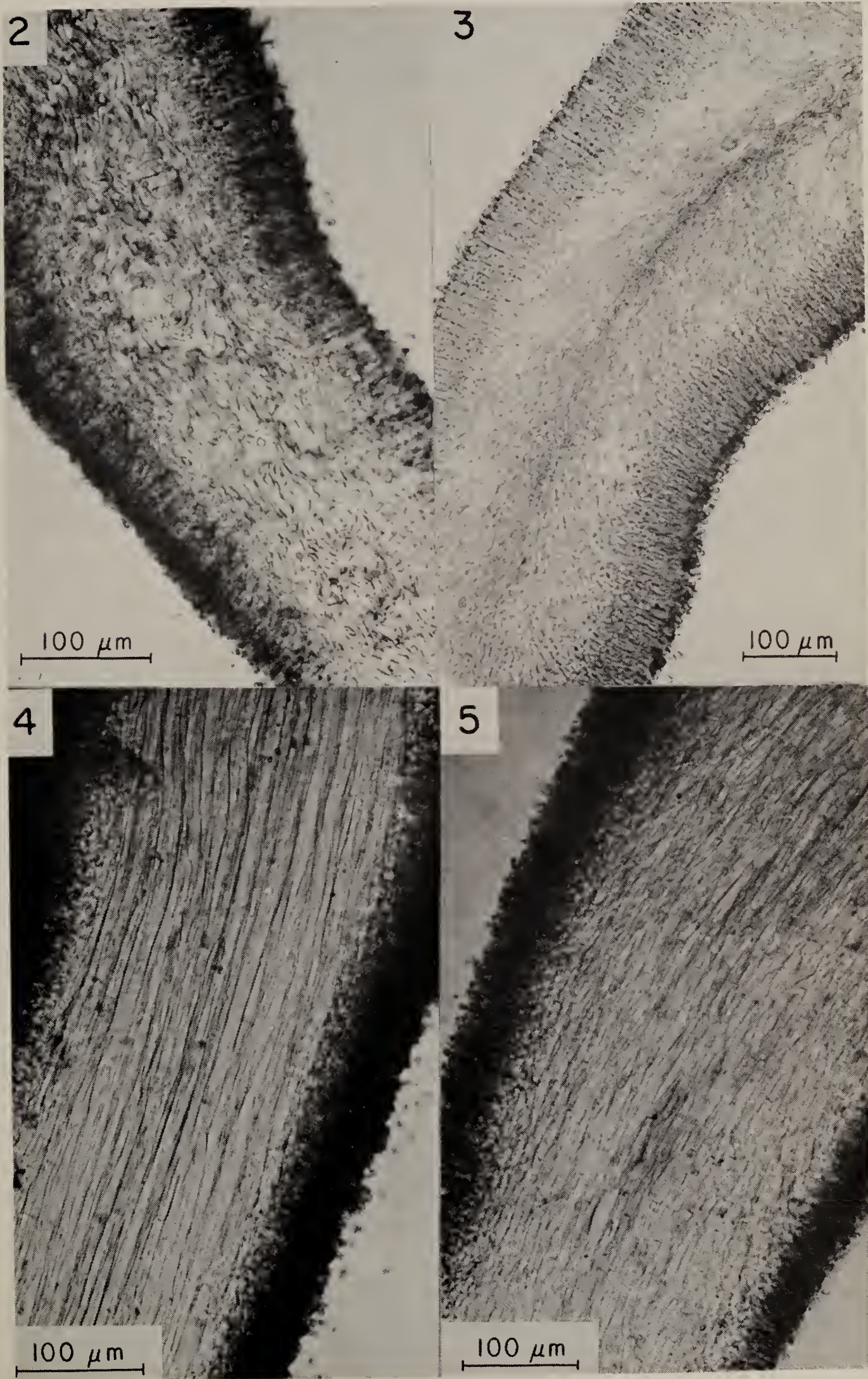
Viscosity of the pileus becomes important at the subsectional level of infrageneric classification. Even when not macroscopically apparent, pileal gluten can be revealed in radial sections of either fresh or dried material. However, the pellicle may be altered by drying; for example, an ixotrichodermium may revive as an ixocutis (Hesler & Smith 1963). Species of subsection *Hygrocybe* have less organized cuticles that sometimes do not revive at all, and should be sectioned when fresh.

E. Stipe Surface. Procedures for examining stipe surfaces were similar to those for the pileal cuticle. Stipe gluten, also important at the level of subsection, is either a viscid outer layer extending over the entire stipe, or a partial veil sheathing only the lower portion. Such gelatinous surfaces are usually less persistent than pileal gluten, and are often difficult to detect. Gelatinous veils may be absorbed into the fibrous context of the stipe, and are frequently absent in mature sporocarps. Then, radial sections of fresh material, taken from the base or near the superior annular zone, will sometimes reveal velar remnants.

Descriptions

Both the macroscopic and microscopic descriptions are taken from fresh

Figs 2-5. Types of lamellar trama in *Hygrophorus*. Fig 2. Interwoven trama, from *H. borealis* f. *borealis*; characteristic of Sections *Camarophylloopsis* and *Hygrotrama*; the preparation was made from dried material, and the hyphae have straightened slightly. Fig 3. Divergent trama, from *H. pudorinus* var. *pudorinus* f. *pudorinus*; characteristic of Section *Hygrophorus*. Fig 4. Parallel trama, *H. conicus* type, from *H. conicus* var. *conicus*, occurs primarily in the conic series of Section *Hygrocybe*. Fig 5. Parallel trama, *H. coccineus* type, from *H. miniatus* var. *miniatus*; present in Section *Lignicolohygrophorus* and most of Section *Hygrocybe*, where it intergrades with both the preceding type and the interwoven type.



specimens when available. For species represented only by earlier collections, and for which field notes were lacking, macroscopic data are compiled from various published descriptions or quoted from Hesler and Smith (1963), while the microscopic description is derived from our study of the dried specimens.

The *Reinhold Color Atlas* (Kornerup & Wanscher 1962) was used in most cases for identifying coloration of sporocarps. Color names followed by a code symbol in parentheses, consisting of 2 numbers and a letter, are taken from this source. Our descriptions also include the nearest color equivalent in the ISCC-NBS centroid color charts (Kelly & Judd 1955), as this publication is still in print and is becoming the standard color reference for agaricology. Colors not identified by an ISCC number are generalized terms and not taken from the ISCC dictionary. Color names in quotation marks in the quoted descriptions are from *Color Standards and Color Nomenclature* (Ridgway 1912).

Descriptive terminology apart from color names largely follows that of Snell and Dick (1957). The term "resinous," applied to the pileal surface, refers to a slight tackiness and not to a visual characteristic. "Brachybasidiole" is used as defined by Smith (1966).

Illustrations

In most cases, descriptions of species are accompanied by a photograph of carpophores, plus camera lucida drawings below of basidia (left) and spores (right). Other structures, when illustrated, are labelled accordingly. In keeping with current mycological conventions, photographs of carpophores are scaled thus: x 1.0, x .75; this figure is a multiple of a single linear dimension, and does not refer to the relative overall size, which is the square of this magnification factor.

The Genus Hygrophorus Fr.

Hygrophorus Fr., Gen. Hymen., p. 8. 1836.

- Syn: *Hygrocybe* (Fr.) Kummer, Fuhr in Pilzk., p. 111. 1871.
Camarophyllus (Fr.) Kummer, Fuhr in Pilzk., p. 117. 1871.
Limacium (Fr.) Kummer, Fuhr in Pilzk., p. 118. 1871.
Godfrinia Maire, Rech. Cyt. Tax. Basidiomycetes, p. 116. 1902.
Hydrophorus (Batt.) Earle, Bull. N.Y. Bot. Gard. 5: 431. 1909.
Hydrocybe (Karst.) Murrill, North Amer. Flora 9: 376. 1916.
Hygroaster Singer, Sydowia 9: 370. 1955.
Hodophilus Heim, Les Champ. d'Europe, p. 219. 1957.
Hygrotrama Singer, Sydowia 12: 221. 1958.
Humidicutis Singer, Sydowia 12: 225. 1958.

Type Species: *Hygrophorus eburneus* (Bull. ex Fr.) Fr.

Spores white in deposit, smooth or rarely nodulose, inamyloid or amyloid, basidia typically narrowly clavate, 5-6 times the spore length; lamellae thick, acute-edged, typically subdistant, presenting a clean waxy appearance, long-decurrent to almost free; pileus thin or fleshy, often hygrophanous and fragile; stipe central and confluent with pileus; partial veil present or absent; sporocarps mostly terrestrial rarely lignicolous, in forests, bogs, or grassy areas; frequently highly colored.

Synopsis of the Genus Hygrophorus in Nova Scotia

Genus HYGROPHORUS Fries

Subgenus HYGROPHORUS

Section CAMAROPHYLLOPSIS Hes. & Sm.

Subsection CAMAROPHYLLOPSIS

Series VIRGINEI (Bataille) Hes. & Sm.

1. *H. niveus* Fr.
2. *H. borealis* Pk. f. *borealis*
3. *H. virgineus* (Fr.) Fr.

Series VISCIDI (Sm. & Hes.) Hes. & Sm.

4. *H. rainierensis* Hes. & Sm.
5. *H. colemannianus* Blox. apud Berk.
6. *H. murinus* Bird & Grund

Series CAMAROPHYLLOPSIS

7. *H. pratensis* (Fr.) Fr. var. *pratensis*

Subsection MICROSPORI (Sm. & Hes.) Hes. & Sm.

Series MICROSPORI

8. *H. canescens* Sm. & Hes.

Section HYGROTRAMA (Sing.) Hes. & Sm.

9. *H. hymenoccephalus* Sm. & Hes.
10. *H. subfuscescens* Sm. & Hes. var. *subfuscescens*

Section HYGROPHORUS

Subsection HYGROPHORUS

Series CHRYSODONTINI (Sing.) Hes. & Sm.

11. *H. chrysodon* (Fr.) Fr.

Series HYGROPHORUS

12. *H. eburneus* (Fr.) Fr.

Series AUREI (Bataille) Hes. & Sm.

13. *H. speciosus* Pk. var. *speciosus*
 14. *H. flavodiscus* Frost apud Pk.
 15. *H. gliocyclus* Fr.
 16. *H. hypothejus* (Fr.) Fr.

Series OLIVACEOUMBRINI (Fr.) Hes & Sm.

17. *H. olivaceoalbus* (Fr.) Fr. var. *olivaceoalbus*
 18. *H. fuliginus* Frost apud Pk.
 19. *H. tephroleucus* (Fr.) Fr. var. *tephroleucus*
 20. *H. pustulatus* (Fr.) Fr.

Subsection CAMAROPHYLLI (Fr.) Hes. & Sm.

Series PUDORINI (Bataille) Hes. & Sm.

21. *H. pudorinus* (Fr.) Fr. var. *pudorinus* f. *pudorinus*

Series RUBENTES (Fr.) Hes. & Sm.

22. *H. purpurascens* (Fr.) Fr.
 23. *H. capreolarius* (Kalchbr.) Sacc.
 24. *H. erubescens* (Fr.) Fr. var. *erubescens*
 25. *H. russula* (Fr.) Quél.

Series FULVENTES (Fr.) Hes. & Sm.

26. *H. tennesseensis* Sm. & Hes.
 27. *H. pacificus* Sm. & Hes.
 28. *H. monticola* Hes. & Sm.

Series CAMAROPHYLLI

29. *H. inocybiformis* Sm.
 30. *H. camarophyllus* (Fr.) Dumée, Grandjean, & Maire
 31. *H. agathosmus* Fr.
 32. *H. odoratus* Sm. & Hes.

Section LIGNICOLOHYGROPHORUS sec. nov.

33. *H. lignicola* sp. nov.

Section HYGROCYBE Fr.

Subsection PSITTACINI Bataille

Series PURI Hes. & Sm.

34. *H. ruber* Pk.

Series PSITTACINI

35. *H. psittacinus* (Fr.) Fr. var. *psittacinus*
 36. *H. laetus* (Fr.) Fr.
 37. *H. minutulus* Pk.
 38. *H. nitidus* B. & C.
 39. *H. ceraceus* (Fr.) Fr.
 40. *H. chlorophanus* (Fr.) Fr.

Series INOLENTES (Bataille) Hes. & Sm.

41. *H. unguinosus* (Fr.) Fr. var. *unguinosus*

Subsection PUNICEI Fayod

Series CONICI (Fayod) Hes. & Sm.

42. *H. conicus* (Fr.) Fr. var. *conicus*
 43. *H. conicus* (Fr.) Fr. var. *atrosanguineus* Grund & Harrison

Series PUNICEI

44. *H. flavescens* (Kauff.) Sm. & Hes.
 45. *H. puniceus* (Fr.) Fr.
 46. *H. marchii* Bres.

Subsection HYGROCYBE

Series MARGINATI ser. nov.

47. *H. marginatus* Pk. var. *marginatus*

48. *H. marginatus* var. *concolor* Sm.

Series HYGROCYBE

49. *H. cantharellus* (Schw.) Fr.

50. *H. miniatus* (Fr.) Fr. var. *miniatus*

Series COCCINEI (Fayod) Hes. & Sm.

51. *H. nitiosus* Blytt

52. *H. coccineus* (Fr.) Fr. sensu Ricken

53. *H. macrosporus* sp. nov.

Complexes

In our collections, we encountered several specimens that appeared to be intermediate between established species or varieties. Further collection and examination yielded an intergrading series of specimens that keyed to either one taxon or the other, depending on the degree of expression of the key characteristics; however, they did not fully satisfy the description of either taxon. As the variants themselves were not uniform we chose to consider them as complexes rather than propose a new species or variety.

The *Hygrophorus olivaceoalbus* Complex.

The complex intergrades between *H. olivaceoalbus* var. *olivaceoalbus* and *H. olivaceoalbus* var. *gracilis* Maire. In this work and in the literature, the typical variety is restricted to specimens having spores about 9-12.5 μm long borne on 4-spored basidia. Hesler and Smith (1963 p. 294) describe var. *gracilis* as a constant, slender form with spores 10-14 μm long borne on 2-, 3-, 4-spored basidia in a single pileus. Its primary distinguishing feature is the dark brown granulation within the cuticular hyphae when treated with Melzer's reagent.

The following are examples of the intergradation:

ACAD 12118—stature stout, as in var. *olivaceoalbus*; cuticular hyphae with yellow-brown granules in Melzer's reagent; spores 11-15(16) μm long; basidia 2-, 3-, and 4-spored in one gill.

ACAD 12284—some sporocarps slender, others stout; cuticular hyphae yellowish-coagulated in Melzer's reagent but lacking granules; spores 10-14(16) μm ; basidia 2-, 3-, and 4-spored in one gill.

ACAD 12285—stature stout; cuticular hyphae lacking granules; spores 10-13.5(15) μm long; basidia 4-spored.

The first example is closest to var. *gracilis*; the last is closest to var. *olivaceoalbus*. All collections were macroscopically similar to the typical variety.

The *Hygrophorus puniceus*—*H. coccineus* Complex.

Several of our collections resembled *H. puniceus* in color, stature, lamellar attachment, and spore shape. However, they lacked a viscid pileus and subsequently keyed to the very similar *H. coccineus*. The essential difference between these 2 species is the presence of a gelatinous cuticle in *H. puniceus*, supported by arbitrary and variable characteristics such as larger size and adnexed gills. Spores of the 2 species do not differ significantly in size, although most mycologists agree that *H. puniceus* has slightly larger spores.

None of these collections showed a definite pellicle in sections of either fresh or dry material, even in young sporocarps. At most, there were a few subgelatinous hyphae near the surface, or spores and agglutinated amorphous matter adhering to a compact epicutis. The drying process may enhance the visible gelatinization of a pellicle or it may collapse the pellicle beyond revival. However, we found pileal gluten to be a usually persistent and reliable feature. Hesler and Smith (1963) claimed that the *H. puniceus* pellicle is well-organized and demonstrable in even the oldest

carpophores. Thus, as the sporocarps showed no sign of mechanical removal of the pellicle during the drying and pressing process, we concluded that it was absent from the beginning.

It is misleading to consider the specimens as a complex intermediate between *H. puniceus* and *H. coccineus*. Usually, they are closer to *H. puniceus*, and only the dry pileus connects them to *H. coccineus*. In size of spores and of basidia, and in number of spores per basidium, they display the variability common to *H. puniceus* but not reported in *H. coccineus*. The number of spores per basidium may be consistently 4, or may vary from 1 to 4 in a single mount, with different proportions of each type of basidium from one collection to another. Spore size equals or exceeds the range for *H. puniceus*, depending on the most prevalent type of basidium. The spores are not only ellipsoidal as in *H. coccineus*, but also oblong to subfusiform as in *H. puniceus*. Thus, despite the dry pileus, the microscopic similarity to *H. puniceus* precludes labelling these specimens as *H. coccineus*.

The European species *H. intermedius* Pass., as described by Bresadola (1928), Romagnesi (1962-63), and Poelt and Jahn (1963), corresponds rather closely with the aberrant specimens. As we have not seen an authentic specimen of *H. intermedius*, we hesitate to label our collections as that species.

The *Hygrophorus miniatus* — *H. cantharellus* Complex.

Most authors have recognized that *H. miniatus* and *H. cantharellus* are related, and Kauffman (1918) stated that they intergrade. Our collections include a few specimens combining the diagnostic features of the 2 species. Collection ACAD 12165, growing on a moss (not *Sphagnum*), has the slender stature and spore size of *H. cantharellus*, but a nondepressed pileus and adnate gills more typical of *H. miniatus* var. *miniatus*. Others, while not intermediate, reflect the variability of the 2 species. For example, ACAD 12124, discussed under *H. cantharellus*, is short like *H. miniatus*, while ACAD 12187, discussed under *H. miniatus* var. *miniatus*, is tall and slender like *H. cantharellus*. It is necessary to note the habitat of these 2 species to determine whether stature is a product of heredity or of environment.

Doubtful and Excluded Species

Nine previously recorded *Hygrophorus* species are excluded from this work. Some represent incorrect identification as determined from a study of all collections of the species in the E.C. Smith Herbarium. Others are European species mentioned only once in the records and unavailable for study, or, if available, then lacking data needed to confirm the identification.

1. *Hygrophorus aureus* Arrh. in Fr. This is a European species. The single collection available, ACAD 5263, is probably *H. speciosus* var. *speciosus*.

2. *H. circinans*. A single collection, ACAD 890, bears this name. We have been unable to locate the species in the available literature.

3. *H. distans* Berk. MacKay (1913) provided the first report of this European species. A.H. Smith corrected the identification of ACAD 291 from *H. distans* to *H. monticola*. The amygdaline odor mentioned in descriptions by Masee (1893) and Rea (1922) probably accounts for the misnomer. Singer (1962) listed *H. distans* as a synonym of *Hygrocybe fornicata* (Fr.) Sing. (= *Hygrophorus fornicatus* Fr. in Hesler and Smith, 1963), a species without a distinctive odor.

4. *H. limacinus* Fr. Wehmeyer (1950) considered MacKay's record (MacKay 1913) as doubtful. The species has not been reported since then in Nova Scotia.

5. *H. laurae* Morg. Six of the 7 collections (ACAD-1417, 2010, 2631, 5258, 5259, and 7097) have coarse red-brown squamules on the stipes, and are apparently some

variety of *H. pudorinus*. The other collection, ACAD-294, although confirmed by A.H. Smith, has spores too large for *H. laurae*.

6. *H. odorus*. This European species scarcely ever appears even in the available European literature. Collections ACAD-2644, 2645, and 2646 are apparently *H. monticola*.

7. *H. pallidus* Pk. Collections ACAD-3953 and 7187 have ellipsoidal spores 6-9.5 μm long and are therefore incorrectly identified.

8. *H. peckianus* Howe. Collections ACAD-293 (fide A.H. Smith), 1469, 1470, and 2634 all display a gelatinous cuticle and ellipsoidal spores 6-8(10) μm long, and are therefore incorrectly identified.

9. *H. sciophanus* Fr. This is a European species. Collection ACAD-314 could be the closely related North American counterpart, *H. perplexus* Sm. & Hes. owing to its adnate rather than decurrent gills. However, the ixotrichodermium characteristic of *H. perplexus* is missing from the specimen.

A Technical Key to the Nova Scotian Species of Hygrophorus

Key to Subgenera

1. Lamellar trama interwoven, reddish in KOH; spores amyloid Subgenus PSEUDOHYGROPHORUS, (not in Nova Scotia)
1. Not with the above combination of characters Subgenus HYGROPHORUS

Subgenus HYGROPHORUS

Key to Sections

1. Lamellar trama intricately to moderately interwoven 2.
1. Lamellar trama divergent, parallel, or slightly interwoven 3.
 2. Pileal cuticle not hymeniform; lamellar trama intricately interwoven Section CAMAROPHYLLOPSIS, p. 13.
 2. Pileal cuticle hymeniform; lamellar trama moderately interwoven Section HYGROTRAMA, p. 14.
3. Lamellar trama divergent Section HYGROPHORUS, p. 14.
3. Lamellar trama parallel to slightly interwoven 4.
 4. Sporocarp lignicolous and thick-walled hyphae present in lamellar and pileal tramas; flesh soft but slightly rubbery, not brittle Section LIGNICOLOHYGROPHORUS
 (*H. lignicola* is the only known species, p. 85.
 4. Sporocarp usually terrestrial; thick-walled hyphae absent; flesh waxy and fragile Section HYGROCYBE, p. 17.

Section CAMAROPHYLLOPSIS

Key to Subsections

1. Spores 6-8 μm or more long, ellipsoidal Subsection CAMAROPHYLLOPSIS, p. 23.
1. Spores usually shorter than 6.5 μm , globose or subglobose Subsection MICROSPORI, p. 14.

Subsection CAMAROPHYLLOPSIS

Key to Series

1. Pileus white, not discoloring appreciably Series VIRGINEI, p. 14.
1. Pileus colored when young 2.
 2. Pileus viscid from a gelatinous cuticle Series VISCIDI, p. 14.

- 2. Pileus moist to dry, lacking a gelatinous cuticle Series CAMAROPHYLLOPSIS, p. 14.

Series VIRGINEI
Key to Species

- 1. Spores 6-8 x 4-5 μ m; pileal cuticle not gelatinous *H. pratensis* var. *pratensis*(Series *Camarophyllopsis*), p. 35.
- 1. Spores 7-9.5 μ m or more long 2.
 - 2. Pileus viscid to lubricous from a pellicle 15 μ m or more thick *H. niveus*, p. 23.
 - 2. Pileus moist to dry, resinous at most; subgelatinous cuticular hyphae, if present, form a layer less than 10 μ m deep. 3.
- 3. Spores 7-9.5 x 4-6 μ m (basidia 4-spored); pileal cuticle a thin subgelatinous layer up to 10 μ m deep *H. borealis* f. *borealis*, p. 27.
- 3. Spores 8-10.5 (12.5) x 5-7 μ m; pileal cuticle of nongelatinous hyphae. *H. virgineus*, p. 28.

Series VISCIDI
Key to Species

- 1. Odor of fresh green corn *H. rainierensis*, p. 28.
- 1. Odor mild or not distinctive. 2.
 - 2. Pileus brown or reddish brown, fading to buff; lamellae pinkish *H. colemannianus*, p. 31.
 - 2. Pileus gray, fading to cream; lamellae gray *H. murinus*, p. 32.

Series CAMAROPHYLLOPSIS
Key to Species

- 1. Spores 6-8(8.5) μ m long; pileus rufous to pale orange, fading, not becoming scurfy or squamulose *H. pratensis* var. *pratensis*, p. 35.
- 1. Spores 7-11.5 (15.5) μ m long; pileus red to medium orange, becoming scurfy to squamulose on disc *H. cantharellus* (Series *Hygrocybe*), p. 115.

Subsection MICROSPORI
Series MICROSPORI

- 1. Pileus with canescent fibrils overlying the glabrous, brownish gray surface *H. canescens*, p. 36.

Section HYGROTRAMA
Key to Species

- 1. Pileus pinkish cinnamon fading to pinkish buff; lamellae concolorous or becoming dull brown; stipe becoming blackish. *H. hymenocephalus*, p. 39.
- 1. Pileus pale dingy yellow to yellowish gray *H. subfuscescens* var. *subfuscescens*, p. 39.

Section HYGROPHORUS
Key to Subsections

- 1. Stipe glutinous to viscid from a gelatinous outer veil, or, at least, with a narrow, gelatinous to moist and membranous superior ring where the veil terminates. Subsection HYGROPHORUS, p. 15.
- 1. Stipe dry; veil, if present, fibrillose and not terminating in a thin, gelatinous or moist ring Subsection CAMAROPHYLLI, p. 16.

Subsection HYGROPHORUS

Key to Series

1. Sporocarp white with yellow flecks and floccules on the stipe apex and pileus margin Series CHRYSODONTINI
 (*H. chrysodon* is the only known species, p. 40.)
1. Sporocarp not with the above combination of characters. 2.
 2. Sporocarp entirely white to whitish before maturity
 Series HYGROPHORUS, p. 15.
 2. Sporocarp colored, at least on the pileus disc. 3.
3. Pileus disc yellow, orange, or red Series AUREI, p. 15.
3. Pileus disc umber, olive brown, gray-brown, or gray
 Series OLIVACEOUMBRINI, p. 15.

Series HYGROPHORUS

Key to Species

1. Entire sporocarp persistently white; lamellae adnate to decurrent; spores 6.5-8.5(10) x 4-6 μm *H. eburneus*, p. 43.

Series AUREI

Key to Species

1. Pileus red, fading to orange and finally yellow-orange toward the margin; growing under larch *H. speciosus* var. *speciosus*, p. 44.
1. Pileus yellow overall, or the disc yellow and the margin cream to whitish, or dark olive brownish that changes in age through yellow and finally to red . . . 2.
 2. Pileus olive brown changing to red *H. hypothejus*, p. 53.
 2. Pileus yellowish, a mixed yellow with pallid shades 3.
3. Spores 6-8.5 x 3.5-5 μm *H. flavodiscus* p. 49
3. Spores 8-10(12.5) x 4-5 μm *H. gliocyclus*, p. 50.

Series OLIVACEOUMBRINI

Key to Species

1. Stipe with a fibrillose inner veil of fuscous to brown fibrils that sometimes form ragged rings and patches; stipe gluten evanescent, terminated above by a narrow, gelatinous annulus or a thin, moist, brown ring 2.
1. Stipe not as above 3.
 2. Spores (8.5)9.5-12.5(14.5) μm long; basidia 4-spored
 *H. olivaceoalbus* var. *olivaceoalbus*, p. 53.
 2. Spores 10-15(16) μm long; basidia 2-, 3-, and 4-spored; sporocarps usually not slender *H. olivaceoalbus* complex
3. Apical stipe ornamentation, if present, white and unchanging with age or injury; stipe persistently glutinous, white or slightly gray-streaked as gluten dries, pileus almost uniformly blackish brown when fresh *H. fuligineus*, p. 54.
3. Apical stipe ornamentation soon becoming cinereous to fuscous; stipe soon dry; pileus color paler 4.
 4. Stipe 2-5(7) mm thick at apex, with fine, cinerous fibrillose points to minute fuscous squamules at maturity
 *H. tephroleucus* var. *tephroleucus*, p. 57.
 4. Stipe 5-10 mm thick, coarsely brown-squamulose at maturity.
 *H. pustulatus*, p. 58.

Subsection CAMAROPHYLLI
Key to Series

- 1. Apical stipe ornamentation of white squamules, quickly yellow in KOH, and yellow-brown to red-brown with age or drying Series PUDORINI, p. 16.
- 1. Apical stipe ornamentation, if present, not becoming yellow-brown or red-brown with age or drying 2.
 - 2. Lamellae soon vinaceous-spotted near edges, or becoming vinaceous over all Series RUBENTES, p. 16.
 - 2. Lamellae not changing as above 3.
- 3. Pileus rusty brown, vinaceous brown, tan, or pale yellow-orange Series FULVENTES, p. 16.
- 3. Pileus gray, gray-brown, or blackish brown. Series CAMAROPHYLLI, p. 17.

Series PUDORINI
Key to Varieties and Forms

- 1. Pileus pale tan to salmon-buff; odor not distinctive; stipe base white to yellowish. *H. pudorinus* var. *pudorinus* f. *pudorinus*, p. 62.

Series RUBENTES
Key to Species

- 1. Stipe with a sparse, cottony to appressed-fibrillose annulus 2.
- 1. Stipe lacking an annulus of any sort 3.
 - 2. Pileus and stipe heavily streaked dark vinaceous; annulus the remains of a whitish partial veil, becoming purplish and disappearing at maturity. *H. purpurascens*, p. 65.
 - 2. Pileus streaked dark vinaceous on disc only; stipe sparsely streaked; annulus not the remains of a partial veil (check young sporocarps). *H. erubescens* var. *erubescens*, p. 69.
- 3. Pileus and stipe uniformly dusky vinaceous to vinaceous brown; lamellae paler, becoming sordid pinkish buff at maturity. *H. capreolarius*, p. 66.
- 3. Pileus and stipe colors not uniform, or else paler than above 4.
 - 4. Pileus streaked and spotted dark vinaceous brown on disc, paling to yellowish on margin; spores 6-9.5 x 4-6 μ m *H. erubescens* var. *erubescens*, p. 69.
 - 4. Pileus yellowish at first, slowly becoming unevenly streaked and flushed with pink, sometimes pink overall, or light red-brown on disc; spores (4.5)5-7 x 3-4 μ m *H. russula*, p. 70.

Series FULVENTES
Key to Species

- 1. Taste of pileal context bitter and odor of raw potatoes *H. tennesseensis*, p. 73.
- 1. Taste and odor not as above 2.
 - 2. Pileus disc rusty brown to tawny; lamellae adnate, or decurrent by a tooth at the most *H. pacificus*, p. 74.
 - 2. Pileus disc tan or vinaceous; lamellae decurrent. *H. monticola*, p. 74.

Series CAMAROPHYLLI

Key to Species

1. Pileus dry (check by sectioning) 2.
1. Pileus viscid 3.
 2. Spores 9.5-17 x 6-9 μm ; unexpanded pileus conic; stipe brown-streaked from a fibrillose veil *H. inocybiformis*, p. 77.
 2. Spores 7-11 x 4-6 (6.5) μm ; unexpanded pileus convex; stipe innately brownish, lacking a veil. *H. camarophyllus*, p. 78.
3. Stipe with ragged, fuscous or brown streaks and zones remaining from a fibrillose veil; pileus brownish. *H. olivaceoalbus* var. *olivaceoalbus*, p. 53, or the *H. olivaceoalbus* complex (Series *Olivaceoumbrini*)
3. Stipe not as above 4.
 4. Odor distinctive; stipe white or becoming ashy to yellowish with age, but not fuscous-dotted 5.
 4. Odor not distinctive; mature stipe with fine to coarse brown squamules *H. tephroleucus* var. *tephroleucus*, p. 57. or *H. pustulatus*, p. 58. (Series *Olivaceoumbrini*)
5. Spores 7-11 μm long; odor amygdaline; pileus persistently gray or brownish gray *H. agathosmus*, p. 81.
5. Spores 9.5-12.5(14) μm long; odor aromatic; pileus gray, becoming yellow-tinged with age *H. odoratus*, p. 82.

Section HYGROCYBE

Key to Subsections

1. Stipe and pileus both viscid (check fresh, moist specimens). Subsection PSITTACINI (below)
1. Stipe dry; pileus viscid or not. 2.
 2. Pileus viscid Subsection PUNICEI, p. 18.
 2. Pileus moist to dry Subsection HYGROCYBE, p. 18.

Subsection PSITTACINI

Key to Series

1. Pileus conic. Series PURI, p. 17.
1. Pileus convex to depressed 2.
 2. Pileus color in red, yellow, or green ranges Series PSITTACINI, p. 17.
 2. Pileus color gray to dull brown, drab Series INOLENTES, p. 18.

Series PURI

Key to Species

1. Pileus red, not blackening; spores 7.5-12.5 x 4-8 μm *H. ruber*, p. 89.

Series PSITTACINI

Key to Species

1. Sporophore bright olive green at first, soon fading to yellow but green persisting at stipe apex and gill edges; odor not distinctive *H. psittacinus* var. *psittacinus*, p. 90.
1. Sporophore not green, or green tints drab and confined to pileus and gill faces, and then odor mephitic 2.
 2. Pileus color a mixture of sordid olive, reddish, and yellow, fading to yellowish; stipe apex often pinkish livid; odor mephitic *H. laetus*, p. 93.

- 2. Pileus and stipe colors not as above 3.
- 3. Pileus red when young, slowly fading to yellow; disc not depressed
..... *H. minutulus*, p. 94.
- 3. Pileus yellow-orange or yellow when young, depressed or not 4.
- 4. Cheilocystidia filiform; odor mephitic *H. laetus*, p. 93.
- 4. Cheilocystidia absent; odor not distinctive 5.
- 5. Pileus yellow, fading to white, convex-umbilicate to infundibuliform,
persistently viscid *H. nitidus*, p. 97.
- 5. Pileus not fading to white, not umbilicate or infundibuliform. 6.
- 6. Lamellae adnate to subdecurrent. *H. ceraceus*, p. 98.
- 6. Lamellae adnexed to emarginate *H. chlorophanus*, p. 101.

Series INOLENTES
Key to Species

- 1. Pileus and stipe dark grayish brown to gray; odor not distinctive; clamp
connections rare *H. unguinosus* var. *unguinosus*, p. 101.

Subsection PUNICEI
Key to Series

- 1. Pileus sharply to bluntly conic, expanding. Series CONICI, p. 18.
- 1. Pileus obtuse to convex or depressed. Series PUNICEI, p. 18.

Series CONICI
Key to Species

- 1. Sporocarp blackening with age or injury; pileus red 2.
- 1. Sporocarp not blackening; pileus orange, fading to yellow, obtusely conic at
most. *H. flavescens* (Series *Punicei*), p. 106.
- 2. Odor not distinctive; pileus medium red fading to streaky orange
..... *H. conicus* var. *conicus*, p. 102.
- 2. Odor strongly aromatic, pileus deep blood red, not fading
..... *H. conicus* var. *atrosanguineus*, p. 105.

Series PUNICEI
Key to Species

- 1. Pileus orange when young, fading to yellow *H. flavescens*, p. 106.
- 1. Pileus red when fresh and moist. 2.
- 2. Spores (8)8.5-12.5(13.5) μ m long; pellicle well-developed, usually more
than 100 μ m deep; sporophores robust *H. puniceus*, p. 109.
- 2. Spores (6.5)7-11(12) μ m long; pellicle thin, less than 100 μ m deep;
sporophores slender, small *H. marchii*, p. 110.

Subsection HYGROCYBE
Key to Series

- 1. Pileus conic Series MARGINATI
- 1. Pileus convex to depressed 2.
- 2. Pileus becoming fibrillose-scurfy to squamulose on the disc at
maturity Series HYGROCYBE, p. 19.
- 2. Pileus remaining glabrous to appressed fibrillose
..... Series COCCINEI, p. 19.

Series MARGINATI

Key to Species

1. Lamellae bright orange, the color persisting at least on the edges after the pileus fades or is dried. *H. marginatus* var. *marginatus*, p. 111.
1. Lamellae yellow-orange, concolorous with the pileus or at least not brighter than it. *H. marginatus* var. *concolor*, p. 115.

Series HYGROCYBE

Key to Species

1. Pileus dull brown; context slowly bruising pinkish brown; odor nitrous. *H. nitiosus* (Series *Coccinei*), p. 120.
1. Pileus scarlet, fading to orange or yellow-orange 2.
 2. Lamellae long-decurrent *H. cantharellus*, p. 115.
 2. Lamellae adnate-subdecurrent to adnexed *H. miniatus* var. *miniatus*, p. 119.

Series COCCINEI

Key to Species

1. Pileus dull brown; context and lamellae slowly bruising pinkish to brown; odor nitrous *H. nitiosus*, p. 120.
1. Pileus red to yellow 2.
 2. Pileus red when moist and fresh, streaked with orange when faded 3.
 2. Pileus some shade of yellow or orange 4.
3. Spores 8-10.5(11) μm long; basidia 4-spored *H. coccineus*, p. 123.
3. Spores (7)10.5-14(15) μm long; basidia 1-, 2-, 3-, or 4-spored in varying proportions *H. puniceus* - *H. coccineus* complex
 4. Lamellae bright orange, the color persisting at least on the edges after the pileus fades; spores 7-11.5 μm long. *H. marginatus* var. *marginatus* (Series *Marginati*), p. 111.
 4. Lamellae yellow to light yellow-orange. 5.
5. Lamellae free; spores 12-16.5(18) μm long; basidia mostly 2-spored *H. macrosporus*, p. 124.
5. Lamellae adnate to decurrent, spores 6-10 μm long, basidia mostly 4-spored 6.
 6. Clamp connections present; spores 3-5 μm broad *H. ceraceus* (Series *Psittacini*), p. 98.
 6. Clamp connections absent; spores 6-7 μm broad *H. marginatus* var. *concolor* (Series *Marginati*), p. 115.

Field Key to the Nova Scotian Species of Hygrophorus

We include a key based entirely on macroscopic features, as an alternative to the technical key when facilities for microscopy are not immediately available.

Collections to be identified with the field key should consist of fresh sporocarps in various stages of maturity. In *Hygrophorus*, sporocarps may change dramatically in color, shape, and surface characteristics from their first emergence to old age, and single specimens thus may not exhibit key features. As weather also influences color and viscosity to some degree, it is important to consider whether colors have been bleached by prolonged exposure to sunlight, or if gelatinization of cuticles has been hampered by drought, or whether gelatinous layers have been washed away by heavy rain. Distinctive odors, when present, are usually evanescent, and may not be detectable in old or dry specimens. Further, as some species have specific habitats or mycorrhizal affiliation, it is necessary to note associated vegetation at the time of collection.

A word of caution is appropriate here. The field key should not be regarded as an easy, foolproof substitute for the technical key. Like most large genera of Agaricales, *Hygrophorus* contains a number of closely similar species separable only by critical inspection of their microscopic as well as macroscopic anatomy. Exclusive reliance on the field key could cause new records for the province to be misidentified, as their distinguishing features may not occur in the key; such anomalies are more likely to be detected in the technical key. In any case, identifications made with the field key should be checked by microscopic examination.

1. Sporocarps lignicolous; pileus and stipe pallid yellowish, pruinose-tomentose. *H. lignicola*, p. 85.
1. Sporocarps terrestrial, or in moss or humus. 2.
 2. Odor aromatic, or of raw potatoes, freshly husked corn, almonds, or otherwise distinctive 3.
 2. Odor not distinctive (mild) or absent. 11.
3. Odor and taste of almonds (amygdaline); carpophores yellow-buff, robust. *H. monticola*, p. 74.
3. Not as above; if odor amygdaline, then taste unpleasant 4.
 4. Odor of raw potatoes or jasmine *H. tennesseensis*, p. 73.
 4. Odor otherwise 5.
5. Odor of green (freshly husked) corn *H. rainierensis*, p. 28.
5. Odor otherwise 6.
 6. Pileus bright red, blood red, reddish orange, orange, yellowish orange, or pinkish orange; stipe more or less concolorous. 7.
 6. Pileus pallid dingy yellowish, gray, russet, or brown; stipe paler. 8.
7. Pileus deep blood red and bruising black; lamellae yellow, also bruising black; odor aromatic *H. conicus* var. *atrosanguineus*, p. 105.
7. Pileus not colored as above; odor mephitic *H. laetus*, p. 93.
 8. Flesh slowly bruising pinkish to brown; odor nitrous, penetrating *H. nitiosis*, p. 120.
 8. Flesh not bruising; odor otherwise. 9.
9. Pileus tawny or rusty brown, at least on the disc *H. pacificus*, p. 74.
9. Pileus gray, lacking brown or yellow tints except at maturity 10.
 10. Odor amygdaline; stipe white, cinerescient; pileus persistently gray *H. agathosmus*, p. 81.
 10. Odor aromatic; stipe not cinerescient; pileus developing yellowish tints with age *H. odoratus*, p. 82.
11. Sporocarps entirely white or whitish, or white with yellow granules on pileal margin and/or stipe apex 12.
11. Sporocarps colored, at least on pileal disc 16.
 12. Sporocarp with yellow granules on pileal margin and/or stipe apex *H. chrysodon*, p. 40.
 12. Sporocarp not as above. 13.
13. Pileus viscid 14.
13. Pileus dry or moist, but not viscid 15.
 14. Pileus usually under 3 cm diameter, margin translucent-striate moist; stipe not viscid *H. niveus*, p. 23.
 14. Pileus usually over 3 cm diameter, not striate; stipe viscid when young. *H. eburneus*, p. 43.
15. Pileus glabrous, persistently white, faintly striate when moist; stipe initially stuffed, soon hollow *H. borealis* f. *borealis*, p. 27.
15. Pileus pruinose or fibrillose in age, becoming pallid yellowish on disc, not striate (may be striatulate when wet); stipe solid, becoming stuffed at maturity *H. virgineus*, p. 28.

- 16. Pileus pinkish buff or pale tan; stipe stout, white with coarse apical squamules which turn yellow-brown to red-brown with age
 *H. pudorinus* var. *pudorinus* f. *pudorinus*, p. 62.
- 16. Not with the above combination of characters 17.
- 17. Pileus scarlet, reddish orange, orange, yellowish orange or yellow, at least on disc. 18.
- 17. Pileus pallid, beige, dingy yellow-brown, brown, olive, gray, pinkish or dull vinaceous, or in combinations of these colors. 40.
- 18. Pileus conic, red fading to orange tones; sporocarps slowly bruising gray, then black. *H. conicus* var. *conicus*, p. 102.
- 18. Not with the above combination of characters. 19.
- 19. Pileus viscid to glutinous 20.
- 19. Pileus moist or dry 33.
- 20. Stipe viscid except at apex, or with only a sparse gelatinous superior ring, whitish overall or streaked yellow, orange or olive-brown beneath a white or yellow apex. 21.
- 20. Stipe not viscid, or viscid over entire length, not annulate, and strongly colored overall 25.
- 21. Pileus with reddish or dark orange colors 22.
- 21. Pileus with yellow colors 23.
- 22. Red color present only in old pilei, and disc tending to remain brown; under 2-needle pines. *H. hypothejus*, p. 53.
- 22. Red color present in young pilei, persisting at least on the disc; under larch. *H. speciosus* var. *speciosus*, p. 44.
- 23. Pileal disc persistently brown, margins yellowish *H. hypothejus*, p. 53.
- 23. Pileal disc yellow, margins yellow to whitish. 24.
- 24. Lamellae yellowish in age; yellow tints on mature stipe caused by colored surface fibrils *H. gliocyclus*, p. 50.
- 24. Lamellae persistently whitish; yellow tints on stipe caused by gelatinous veil *H. flavodiscus*, p. 49.
- 25. Stipe viscid to glutinous. 26.
- 25. Stipe not viscid (do not handle excessively, or some stipes may become slightly tacky). 31.
- 26. Pileus conic, in age plane with a small acute umbo, red fading to orange *H. ruber*, p. 89.
- 26. Pileus convex to plane. 27.
- 27. Pileus and lamellae yellow-orange with green tints on edges.
 *H. psittacinus* var. *psittacinus*, p. 90.
- 27. Pileus and lamellae lacking green tints 28.
- 28. Pileus and stipe initially red, fading to yellowish.
 *H. minutulus*, p. 94.
- 28. Pileus and stipe not red in young sporocarps 29.
- 29. Lamellae adnexed to emarginate *H. chlorophanus*, p. 101.
- 29. Lamellae adnate to decurrent 30.
- 30. Margin incurved in young pilei; old pileus fading whitish; pileus and stipe persistently viscid *H. nitidus*, p. 97.
- 30. Margin not incurved; pileus not fading whitish; pileus and stipe subviscid, soon drying. *H. ceraceus*, p. 98.
- 31. Pileus yellow to orange-yellow, lacking red tints. *H. flavescens*, p. 106.
- 31. Pileus persistently red, with partial fading to orange or yellow-orange in age. 32.
- 32. Stipe over 5 mm thick; pileus obtusely conic or with pronounced umbo. *H. puniceus*, p. 109.
- 32. Stipe less than 5 mm thick; pileus convex to centrally depressed
 *H. marchii*, p. 110.

- 33. Pileal disc fibrillose-scurfy, usually depressed at maturity 34.
- 33. Pileal disc not as above 35.
 - 34. Lamellae clearly decurrent *H. cantharellus*, p. 115.
 - 34. Lamellae adnexed to adnate *H. miniatus* var. *miniatus*, p. 119.
- 35. Sporocarp uniformly yellow to yellow-orange. 36.
- 35. Sporocarp orange or with pronounced dark orange tints 38.
 - 36. Lamellae free *H. macrosporus*, p. 124.
 - 36. Lamellae adnate to uncinata. 37.
- 37. Pileus conic; stipe over 4 mm thick.
 - *H. marginatus* var. *concolor*, p. 115.
- 37. Pileus not conic; stipe under 4 mm thick *H. ceraceus*, p. 98.
 - 38. Lamellae persistently brilliant orange, at least on edges
 - *H. marginatus* var. *marginatus*, p. 111.
 - 38. Lamellae not so colored 39.
- 39. Lamellae decurrent at maturity; pileus tawny or rarely carrot red, fading to orange or tan. *H. pratensis* var. *pratensis*, p. 35.
- 39. Lamellae not decurrent; pileus and stipe red. *H. coccineus*, p. 123.
 - 40. Pileus whitish; lamellae and stipe yellow *H. nitidus*, p. 120.
 - 40. Not with the above combination of characters. 41.
- 41. Pileus green, at least on margin; stipe viscid over entire length
 - *H. psittacinus* var. *psittacinus*, p. 90.
- 41. Pileus lacking green tints 42.
 - 42. Lamellae whitish with vinaceous spots and stains, or flushed with pink, or dull rose overall. 43.
 - 42. Lamellae not colored as above 47.
- 43. Stipe with a cottony or appressed fibrillose annulus 44.
- 43. Stipe lacking an annulus 45.
 - 44. Annulus resulting from a partial veil, cottony when young; pileus and stipe densely streaked vinaceous *H. purpurascens*, p. 65.
 - 44. Annulus not velar in origin, merely aggregated colored fibrils. Pileus whitish with vinaceous streaks and stains on disc; stipe sparsely streaked vinaceous *H. erubescens* var. *erubescens*, p. 69.
- 45. Pileus and stipe uniformly dusky vinaceous or nearly so; lamellae paler, becoming sordid pinkish buff *H. capreolarius*, p. 66.
- 45. Pileus and stipe colors not uniform, or else paler than above 46.
 - 46. Pileus whitish and streaked or stained dark vinaceous brown on disc.
 - *H. erubescens* var. *erubescens*, p. 69.
 - 46. Pileus becoming unevenly streaked and flushed with pink, or pink overall, or light red-brown on disc. *H. russula*, p. 70.
- 47. Pileus viscid (moisten dry pilei to check) 48.
- 47. Pileus not viscid 55.
 - 48. Stipe viscid over entire length, slender, grayish to blackish; pileus concolorous with stipe. *H. unguinosus* var. *unguinosus*, p. 101.
 - 48. Stipe not viscid, or else viscid to glutinous except at apex 49.
- 49. Lamellae white or whitish 50.
- 49. Lamellae colored 53.
 - 50. Stipe initially white, with squamulose ornamentation which becomes cinereous to fuscous 51.
 - 50. Stipe not as above 52.
- 51. Pileus to 3 cm broad; stipe 2-5 mm thick at apex
 - *H. tephroleucus* var. *tephroleucus*, p. 57.
- 51. Pileus over 3 cm broad; stipe 5-10 mm thick at apex *H. pustulatus*, p. 58.
 - 52. Stipe with fuscous to medium brown streaks and patches except at the white apex, the colored portion initially glutinous but often soon drying *H. olivaceoalbus* var. *olivaceoalbus*, p. 53.

52. Stipe persistently white or whitish, the lower portion persistently glutinous. *H. fuligineus*, p. 54.
53. Lamellae gray, pileus gray to cream *H. murinus*, p. 32.
53. Lamellae colored otherwise. 54.
54. Lamellae pale yellowish green *H. hypothejus*, p. 53.
54. Lamellae buff to pinkish. *H. colemannianus*, p. 31.
55. Lamellae white or whitish 56.
55. Lamellae distinctly colored 57.
56. Young pileus conic; stipe white at apex, with fuscous streaks and patches below *H. inocybiformis*, p. 78.
56. Young pileus convex; stipe brownish overall, the color not in streaks or patches. *H. camarophyllus*, p. 78.
57. Lamellae gray to dull violet; pileus gray-brown to drab rose with an overlying thin layer of surface fibrils *H. canescens*, p. 36.
57. Not as above 58.
58. Lamellae yellowish to grayish yellow; stipe streaked brown, with white apex *H. inocybiformis*, p. 77.
58. Not as above 59.
59. Stipe persistently pale yellow, taste of flesh faintly subnauseous *H. subfuscescens* var. *subfuscescens*, p. 39.
59. Stipe drab yellow-brown, pinkish buff, or brown; taste none *H. hymenocephalus*, p. 39.

Descriptions of the Species

Subgenus HYGROPHORUS

Spores white, smooth or rarely nodulose, amyloid or not. Lamellar trama various, not reddish in KOH.

Section CAMAROPHYLLOPSIS Hes. & Sm. (not *Camarophyllopsis* Herink)

N. Am. Spec. of *Hygrophorus*, p. 48, 1963

Lamellar trama intricately interwoven; pileal cuticle not hymeniform; hymenial cystidia absent; spores smooth, inamyloid.

Type species: *H. pratensis* (Fr.) Fr.

Subsection CAMAROPHYLLOPSIS

Spores at least 6-8 μ m long, ellipsoidal.

Series VIRGINEI (Bataille) Hes. & Sm.

N. Am. Spec. of *Hygrophorus*, p. 49, 1963

Pileus white.

Type species: *H. virgineus* (Fr.) Fr.

1. *Hygrophorus niveus* Fr.

Epicr. Myc., p. 327. 1838.

Camarophyllus niveus (Fr.) Wünsche, Die Pilze, p. 115. 1887.

Hydrocybe nivea (Scop.) Murr., N. Am. Flora 9: 377. 1916.

Figs 6, 7, 8.

Basidiocarp: Pileus 1-3(6) cm broad, obtuse to convex young, later broadly convex to

plane, often depressed or umbilicate, occasionally with small, low umbo, viscid to resinous, glabrous, margin usually conspicuously striate moist; white, becoming pale, yellowish white (2A2) (ISCC-92) in age; context thin (1-3 mm on disc), often hollow on disc in depressed pilei, white, fibrous; odor and taste not distinctive. Lamellae decurrent, concolorous with or slightly more yellowish than the pileus, broad to medium broad (2.5-7 mm), subdistant, sometimes intervenose or forked, thickish, edges even. Stipe 4-5.5 cm long, 3-12 mm thick at apex, concolorous with the pileus, white within, dry, glabrous to satiny, equal or tapering downward, at times subcompressed, stuffed, becoming hollow.

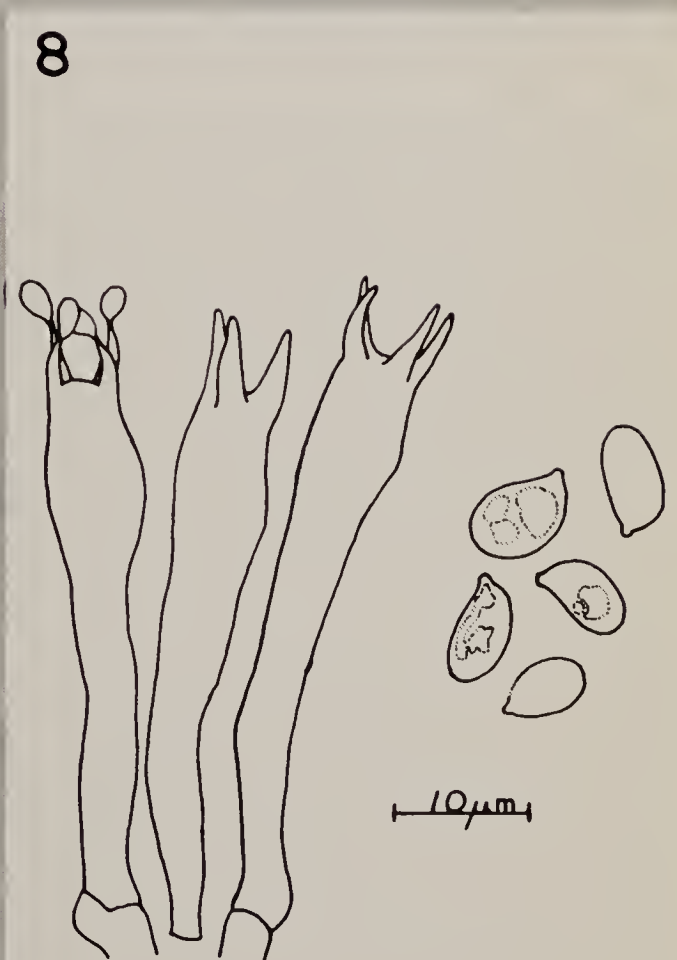
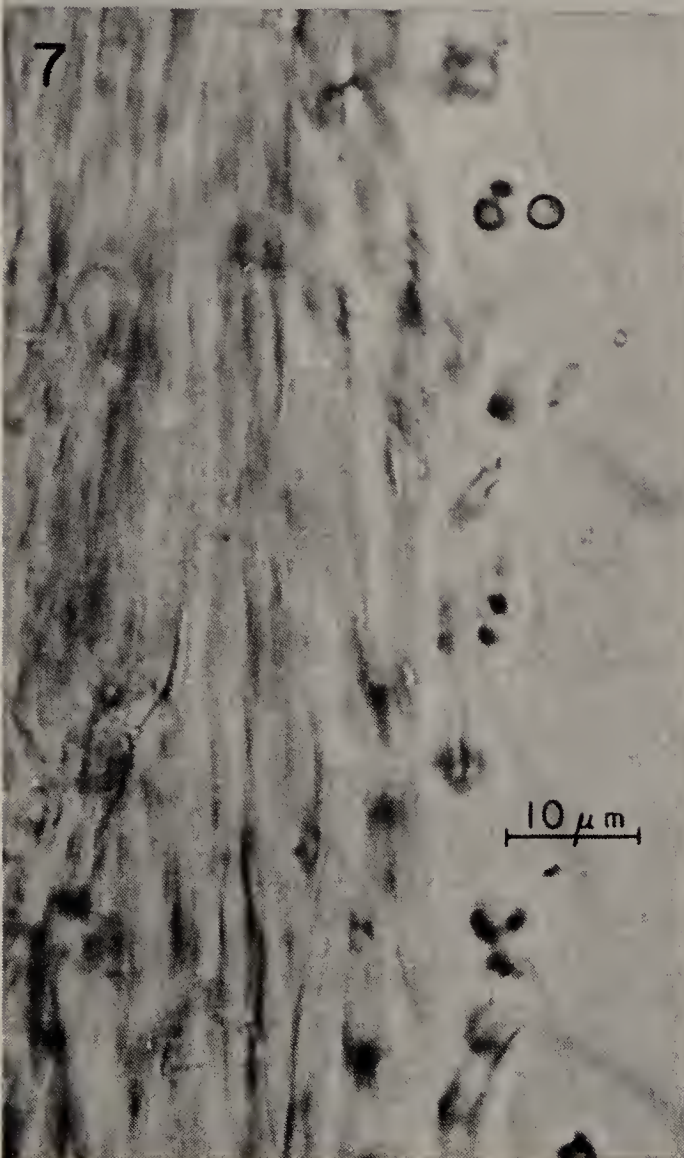
Microscopic Structures: Spores 7-9.5(10.5) x 3.5-5 μ m, obovate to ellipsoidal, occasionally ovate, smooth, inamyloid. Basidia 32-47 x 6-9.5 μ m, long-clavate, slender or rather stout, mostly 4-spored, occasionally 3-spored in the same gill, the sterigmata up to 6 μ m long. Pleurocystidia and cheilocystidia none. Gill trama of interwoven hyphae 2-14 μ m broad. Cuticle a narrow ixocutis 16-40 μ m deep, the hyphae more or less repent and radial, occasionally erect, gelatinized, 2.5-3(5) μ m broad. Pileal trama of radial, interwoven hyphae; hypodermium none. Clamp connections present in the cuticle, gill trama, and pileal trama.

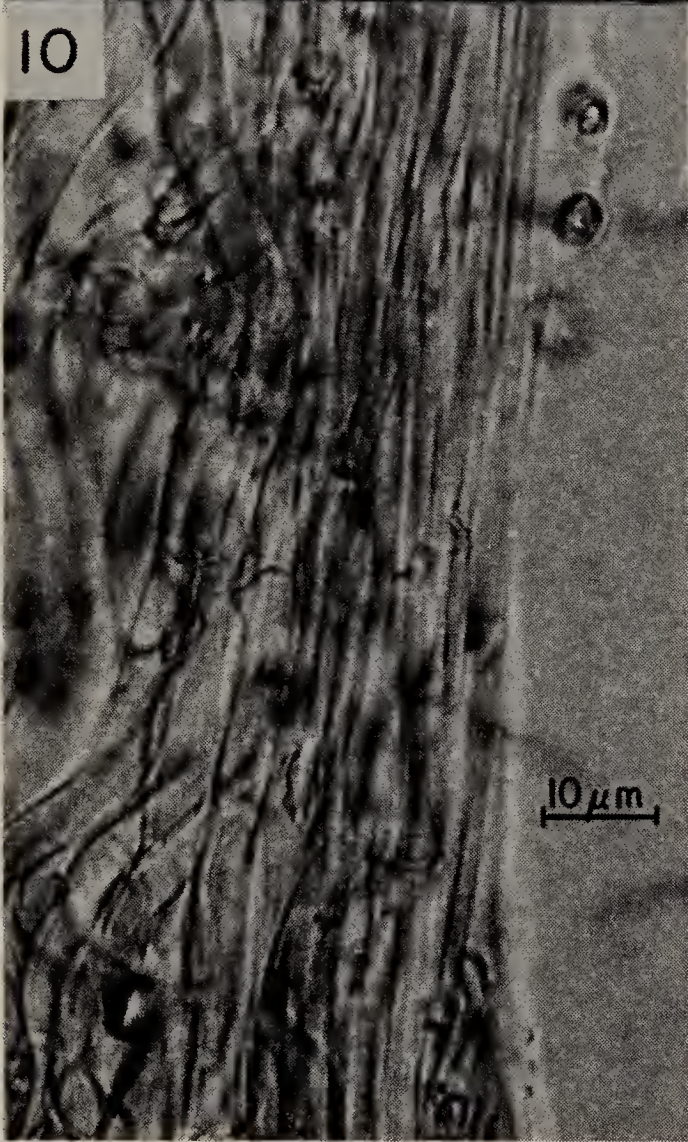
Habit and Habitat: Scattered to gregarious, in grassy clearings or in deciduous woods.

Material Studied: ACAD 12113, Hell's Gate, Kings Co., 21 Oct. 1967; ACAD 12266, Moose River, Pictou Co., 14 Oct. 1968.

Remarks: Typically, *H. niveus* is small, depressed to umbilicate, viscid, and coarsely striate when moist. However, ACAD 12266 is large (pileus up to 6 cm broad), convex and scarcely umbonate, resinous, and non-striate, more like *H. borealis* f. *borealis*. The depth of the pellicle places it in *H. niveus*, with the more typical specimens of ACAD 12113. (See the discussion of *H. borealis* f. *borealis* for further comparison of the 2 species).

Collection ACAD 12206 (Washabuck, Victoria Co., 25 Sept. 1968) answers the description of *H. niveus*, but appears to lack clamp connections, even at the bases of the basidia. As the significance of clamps is poorly understood (Smith, 1966), environmental influence on clamp development should be investigated before such anomalies are classed as distinct varieties.





2. *Hygrophorus borealis* Pk. f. *borealis*

N.Y. State Mus. Ann. Rep. 26:64. 1874.

Camarophyllus borealis (Pk.) Murr., N. Am. Flora 9: 385. 1916

Omphalina tepeitensis Murr., N. Am. Flora 9: 348. 1916.

Figs 9, 10, 11.

Basidiocarp: Pileus 0.5-3 cm broad, at first convex-depressed or disc at least flattened, expanding broadly convex to plane, moist to slightly resinous, margin faintly striate moist; milk white (1A2) (ISCC-104) or whiter, becoming pale, yellowish white (2A2) (ISCC-92) in age; context thin on disc (1-1.5 mm), membranous over gills, whitish, fragile; odor and taste not distinctive. Lamellae decurrent, occasionally adnexed and uncinat, whitish to pale yellow (2A3) (ISCC-104), subdistant, moderately broad (2-2.5 mm), thickish, at times intervenose, edges even. Stipe 2-5.5 cm long, 2-5 mm thick at apex, concolorous with the pileus, white within, dry, glabrous, with a dull pearly lustre, equal or slightly tapered downward, terete, stuffed, soon becoming hollow.

Microscopic Structures: Spores 7-9.5 x 4-6 μm , mostly ellipsoidal, some approaching pyriform or obovate, smooth, inamyloid, Basidia 29-38 x 6.5-11.5 μm , narrowly clavate, rather short, 4-spored, the sterigmata slender, up to 6 μm long. Pleurocystidia and cheilocystidia absent. Gill trama of interwoven hyphae 3.5-14 μm broad. Cuticle a thin layer, 6.5-9.5 μm deep (about 3-5 hyphae), of repent, radial, subgelatinous hyphae 1.7-3 μm broad. Pileal trama of interwoven, radially oriented hyphae 3.5-11.5 μm broad, similar to gill tramal hyphae, gradually transitional to the cuticular hyphae; hypodermium absent. Clamp connections present in the cuticle, lamellar trama, and pileal trama.

Habit and Habitat: Scattered to gregarious in moss and leaf mould under beech and *Osmunda* species.

Material Studied: ACAD 12194, Perry Road, Yarmouth Co., 22 Sept, 1968.

Remarks: This beautiful white fungus is apt to be confused with *H. virgineus* or *H. niveus*. The pileus of *H. virgineus* is moist to dry, and the slightly broader cuticular hyphae are never gelatinous. Moreover, the spores of *H. virgineus* are slightly larger, regularly ranging up to 12 μm long, although Hesler and Smith (1963) mentioned collections of *H. borealis* having 2-spored basidia with spores of this length.

Hygrophorus borealis is very close to *H. niveus* and Singer (1951) has suggested that they may be a single species. The critical difference used by Hesler and Smith (1963), and applied here, is the degree of gelatinization in the cuticle. *H. borealis* has a few, narrow, subgelatinous hyphae on its pileal surface. *H. niveus* possesses a pellicle at least 15 μm thick. Should these features prove variable, *H. borealis* would be synonymous with *H. niveus*.

Figs 9-11. *H. borealis* f. *borealis*. Fig 9. ACAD 12194, X 1.0. Fig 10. pileal cuticle of ACAD 12194 in radial section, showing little or no gelatinization. Fig 11. ACAD 12113, basidia and spores.

3. *Hygrophorus virgineus* (Fr.) Fr.

Epicr. Myc., p. 327. 1838.

Agaricus virgineus Fr., Syst. Myc. 1: 100. 1821.

Camarophyllus virgineus (Fr.) Kummer, Führ. in Pilzk., p. 117. 1871.

Figs 12, 13.

Basidiocarp: Pileus 2-6 cm broad, convex when young, becoming plane to slightly depressed, moist to dry, margin sometimes striatulate when rainsoaked; surface subglabrous centrally, slightly pruinose on margins; white or pallid with yellowish disc; context white, soft, unchanging; odor absent to sometimes pleasant, taste not distinctive. Lamellae decurrent, subdistant to distant, pallid or concolorous with pileus. Stipe 3-8 cm long, 3-8 mm thick, white, tapering, glabrous to slightly pruinose; context solid becoming stuffed, pallid.

Microscopic Structures: Spores 8-10 (12.5) x 5-7 μ m, short-elliptical, rarely obovate, smooth, inamyloid. Basidia 35-50 x 7.5-10 μ m, narrowly clavate, often enlarged at apex, 4-spored, very rarely 1- or 2-spored, the sterigmata stout, up to 6 μ m long. Pleurocystidia and cheilocystidia none. Gill trama of interwoven hyphae 3-16 μ m broad. Cuticle of repent, nongelatinous hyphae 1.5-4 μ m broad, little differentiated from context. Pileal trama of interwoven, radially disposed hyphae 4-17.5 μ m broad; hypodermium none. Clamp connections present in the hyphae of the cuticle, gill trama, and pileal trama.

Habit and Habitat: "Gregarious on soil, at times among moss, in deciduous and coniferous, and mixed woods . . ." (Hesler & Smith 1963).

Material Studied: ACAD 7190, Lake Kejimikujik, Annapolis Co., 22 Sept. 1962.

Remarks: *Hygrophorus virgineus* is easily distinguished from *H. niveus* by its non-viscid pileus and larger spores. Separation from *H. borealis* f. *borealis* is more difficult and depends on the combination of a nongelatinous epicutis and slightly larger spores in *H. virgineus*.

Series VISCIDI (Sm. & Hes.) Hes. & Sm.

N. Am. Spec. of *Hygrophorus*, p. 61. 1963

Pileus other than white, viscid; spores usually longer than 6.5 μ m; lamellar trama interwoven.

Type species: *H. subviolaceus* Pk.

4. *Hygrophorus rainierensis* Hes. & Sm.

N. Am. Spec. of *Hygrophorus*, p. 64. 1963.

Figs 14, 15.

Basidiocarp: Pileus 2.5-5 cm broad, convex becoming plane and often depressed in age, occasionally subumbonate when plane, viscid, glabrous, hygrophanous; margin striatulate, irregular, wavy; gray to olive gray (1E2) (ISCC 113) on disc, becoming medium gray (1E1) (ISCC 265) on margin; context pale gray (1B1) (ISCC 264), thick at disc, unchanging; odor strongly of freshly husked green corn, taste farinaceous and unpleasant to nearly mild. Lamellae deeply decurrent, edges eroded, platinum (1D1) (ISCC 265). Stipe 3-6 cm long, 5-9 mm thick, equal, often curved, dry, glabrous, pallid or whitish, lighter at base, unchanging; context solid, becoming stuffed.

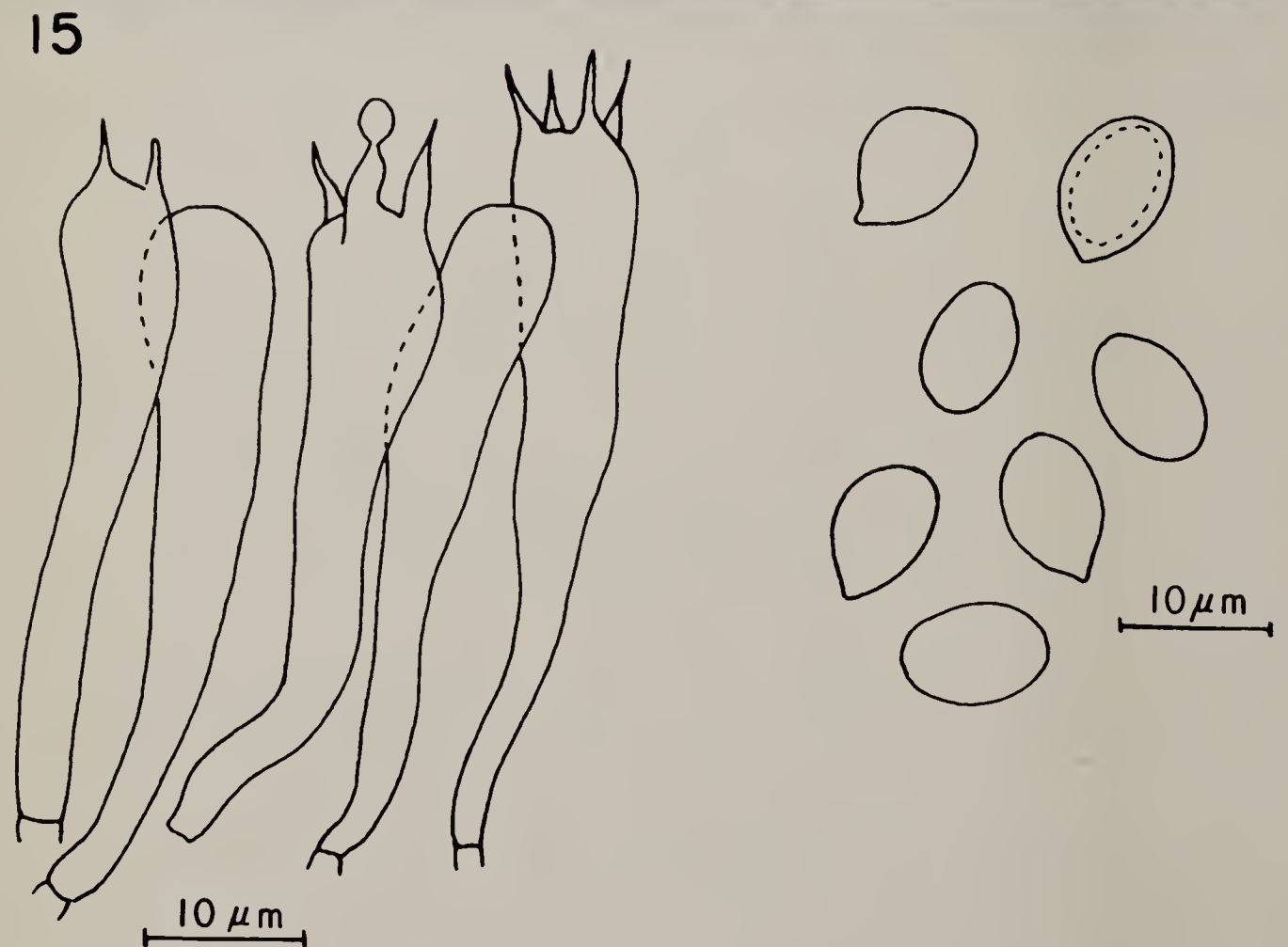
Microscopic Structures: Spores (4.5)6-8(9) x 4-5.5 μ m, subglobose to broadly ellipsoid, inamyloid. Basidia 38-48 x 5-8 μ m, long-clavate, mostly 4-spored. Pleurocystidia and cheilocystidia absent. Lamellar trama interwoven. Cuticle an ixotrichodermium,



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Figs 12, 13. *H. virgineus*. Fig 12. Smith 64497, X 1.5. Fig 13. ACAD 7190, basidia and spores.



Figs 14, 15. *H. rainierensis*. Fig 14. Courtesy of K.A. Harrison, X 1.25. Fig 15. ACAD 11978, basidia and spores.

becoming appressed at maturity, 45-80 (120) μm thick, of irregular hyphae (1.5)2-3.5 μm broad; pileal trama radial. Clamp connections present but rare, small.

Habit and Habitat: Gregarious in coniferous forest.

Material Studied: ACAD 11978, West Gaspereau, Kings Co., 12 Oct. 1977.

Remarks: This species is easily identified by its gray, viscid pileus, decurrent lamellae, and odor of freshly husked green corn. *H. murinus* is similar, but lacks an odor and has much larger spores than *H. rainierensis*. Two other closely related species, *H. nordmanensis* and *H. subviolaceus*, do not occur in Nova Scotia. *H. fuliginus* may superficially resemble *H. rainierensis*, but is extremely glutinous on both stipe and pileus, has a divergent lamellar trama, and also lacks a distinctive odor.

5. *Hygrophorus colemannianus* Blox. apud Berk.

Outl. Brit. Fungol., p. 200. 1860.

Camarophyllus colemannianus (Blox. apud. Berk.) Ricken, Vademecum für Pilzfreunde, p. 197. 1920.

Figs 16, 17.

Basidiocarp: "Pileus 1-4.5 cm broad, obtuse to turbinate, sometimes broadly convex to nearly plane in age or with the margin recurved slightly, sometimes with a low obtuse umbo, the margin decurved, color evenly 'walnut brown' to 'cinnamon brown', hygrophanous, fading to 'fawn color' or 'avellaneous' and finally 'cinnamon buff' to 'vinaceous buff' (dull, deep rusty brown fading to avellaneous or buff), glabrous, viscid and shining, with a thin separable pellicle, the margin translucent striate when moist. Context concolorous with the surface, no color change when bruised, thick under the disc, thin toward the margin, fragile; odor and taste mild.

Lamellae arcuate and soon distinctly decurrent, 'avellaneous' to 'vinaceous buff' fading to 'tilleul buff' (whitish) at times, close to subdistant (20-26 reach the stipe), narrow to moderately broad, many forking near their outer extremities, usually one tier of lamellulae, edges entire.

Stipe 3-6(8) cm long, 4-7 mm thick, white, equal or narrowed toward the base, solid or with a narrow tubule, glabrous, not viscid, apex merely silky and not pruinose." (Hesler & Smith, 1963).

Microscopic Structures: Spores 6.5-8(9.5) x 4.5-6(7) μm , short-elliptical to obovate, smooth, inamyloid. Basidia 40-53(62) x 7-8.5(10.5) μm , clavate, slender, 4-spored, the sterigmata up to 7 μm long. Pleurocystidia and cheilocystidia absent. Gill trama of interwoven hyphae 2-10 μm broad, the mediostrate reviving brownish in KOH where it joins the pileus. Cuticle an ixocutis 43-69 μm deep, the hyphae gelatinous, radial, usually repent but occasionally erect, colorless, 1-3 μm broad. Pileal trama of radial, slightly interwoven hyphae 2.3-11.5 μm broad, reviving brownish in KOH. Clamp connections present in the cuticle, gill trama, and pileal trama.

Habit and Habitat: "Gregarious on humus in oak and beech woods . . ." (Hesler & Smith 1963).

Material Studied: ACAD 288, Agriculture Experimental Station, Kentville, Kings Co., 10 Sept. 1933.

Remarks: *Hygrophorus colemannianus* is distinguished by its brown, viscid pileus, its white stipe, and its whitish to pinkish gills. The hypodermium of radial, parallel, brown hyphae, described by Hesler and Smith (1963), appears to constitute the entire pileal trama in the material examined here.

6. *Hygrophorus murinus* Bird & Grund.

Can. J. Bot. 48: 408-409. 1970.

Figs 18, 19.

Basidiocarp: Pileus 2-6 cm broad, convex, becoming plano-convex, often subumbonate, finally plane to shallowly depressed with uplifted margin, slightly viscid to resinous, glabrous to appressed fibrillose, nougat (5D3) (ISCC-60) or dust (5D2) (ISCC-63), often zonate, bleaching with age to pale cream, sometimes with dark blond (5D4) (ISCC-77) zones or tints on umbo; context 1.5-5.5 mm on disc, thick when young, thinner with age, cinereous under pellicle, whitish elsewhere; odor and taste mild, not distinctive. Lamellae decurrent, birch gray (5C2) (ISCC-63) to dust (5D2) (ISCC-63), bleached and yellowed by age and frost, narrow (2-6.5 mm broad) subdistant, often intervenose, thin to thickish, edges even. Stipe 3-5 cm long, 4-12 mm thick at apex, white, tinted cream, sometimes yellowish at base, especially when handled, appressed fibrillose, equal or tapering downward, terete.

Microscopic Structures: Spores 7-9.5(10.5) x (4.5)5-6 μm , short-elliptical, smooth, inamyloid. Basidia 43-56(68) x 7-9.5 μm , narrowly clavate, 4-spored, the sterigmata stout and prominent, up to 6.5 μm long. Pleurocystidia and cheilocystidia absent. Gill trama interwoven, the hyphae 3-10.5(15.5) μm broad. Cuticle a thin ixotrichodermium, 24-84 μm deep, the hyphae 1-3 μm broad, generally erect, often becoming repent after drying and then forming an ixocutis. Pileal trama of radial, interwoven hyphae 3-25(31) μm broad. Clamp connections conspicuous, present in the cuticle, gill trama, and pileal trama.

Habit and Habitat: Gregarious to subcespitose in hemlock-white birch woods.

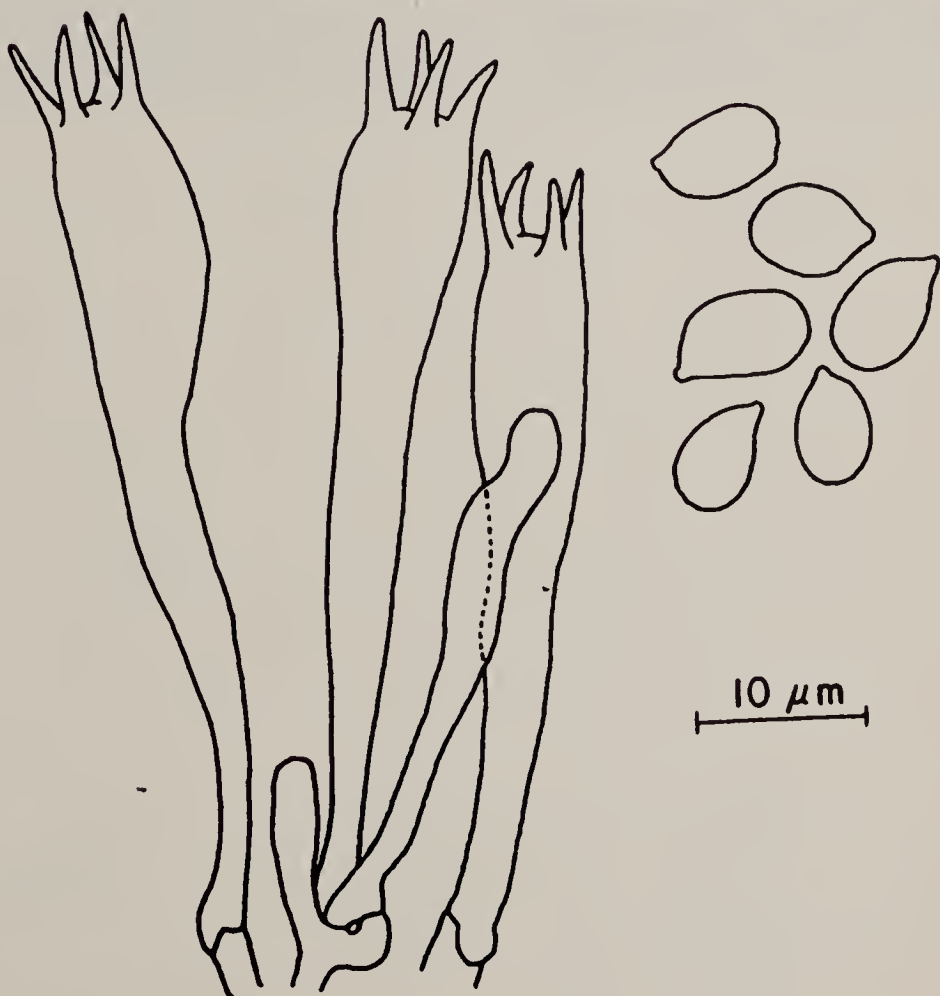
Material Studied: ACAD 12120 (type), Gaspereau Valley, Kings Co., 3 Nov. 1967; ACAD 12258, Waternish, Guysborough Co., 14 Oct. 1968.

Remarks: *Hygrophorus murinus* is one of several related gray-gilled species of Subsection *Camarophylloopsis*. In the most recent North American monograph (Hesler & Smith 1963), this fungus keys to *H. nordmanensis* Hes. & Sm., which differs in having a green-corn odor and lacking clamp connections, although the authors cautioned against stressing the importance of the latter feature. The tendency of the lower stipe to stain yellow places *H. murinus* close to the European species *H. lacmus* Fr.; however, the Nova Scotian material lacks the pileal striations and reddish tints of *H. lacmus*. Moreover, *H. lacmus* has subglobose spores, usually about 6 μm and never more than 7.5 μm long (Lange 1940; Wakefield & Dennis 1950). Bresadola's (1928) description of *H. lacmus* applies to the above Nova Scotian collections, but differs so widely from other concepts of *H. lacmus* that Bresadola appears to be in error. *H. murinus* also closely resembles *H. subviolaceus* Pk., which has a bitter or subnauseous to acrid taste and a pileal context more-or-less concolorous with the pileal surface (Hesler & Smith 1963).

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Figs 16, 17. *H. colemannianus*. Fig 16. Smith 43816, X .65. Fig 17. ACAD 288, basidia and spores.

18



19



Series CAMAROPHYLLOPSIS

Pileus colored, not viscid; spores usually longer than $6.5\ \mu\text{m}$, lamellar trama interwoven.

7 *Hygrophorus pratensis* (Fr.) Fr. var. *pratensis*

Epicr. Myc., p. 326. 1838.

Agaricus pratensis Fr., Syst. Myc. 1: 99. 1821.

Camarophyllus pratensis (Fr.) Kummer, Führ. in Pilzk., p. 118. 1871.

Hydrocybe pratensis (Fr.) Murr., Mycologia 6: 2. 1914.

Camarophyllus fulvosus Murr., N. Am. Flora 9: 387. 1916.

Figs 20, 21.

Basidiocarp: Pileus 1-4 cm broad, convex, expanding to plano-convex and slightly depressed on disc, moist to dry, glabrous to faintly fibrillose, carrot red (6B7) (ISCC-53) overall at first, fading to pale orange (5A3) (ISCC-73) on the margin; context moderately thick on disc (2-2.5 mm), thin to membranous over gills, pallid apricot; odor and taste not distinctive. Lamellae decurrent, pallid yellow to pale orange (5A3) (ISCC-73), moderately narrow (1-3 mm broad), subdistant, forked and intervenose at margin in older specimens, thickish, edges even. Stipe 3.5-4.5 cm long, 5.5-15 mm thick at apex, streaky pallid orange or champagne (4B4) (ISCC-90), whitish at the base, pale yellowish within, dry, glabrous or appressed fibrillose, subequal, sometimes narrowing toward apex, occasionally unevenly compressed and flexuous, stuffed or with narrow hollow.

Microscopic Structures: Spores 6-8(8.5) x 4-6 μm , short-elliptical to subglobose, at times obovate, smooth, inamyloid. Basidia 41-64 x 6.5-7.5 μm , slender, narrowly clavate, 4-spored, the sterigmata stout to slender, up to 5 μm long. Pleurocystidia and cheilocystidia absent. Gill trama of interwoven hyphae 1.7-18.5 μm broad. Cuticle a poorly differentiated epicutis, the hyphae yellowish, more or less radial, non-gelatinous, slightly narrower than those of the context. Pileal trama of interwoven hyphae 2.5-8 μm broad; hypodermium absent. Clamp connections present in the gill and pileal tramas.

Habit and Habitat: Scattered in mixed forest.

Material Studied: ACAD 2639, Agriculture Experimental Station, Kentville, Kings Co., 20 Sept. 1953; ACAD 12248, Moose River, Pictou Co., 14 Oct. 1968.

Remarks: Kauffman (1918) listed a var. *pallidus*, identical with var. *pratensis* except for its whitish pileus. Hesler and Smith (1963) suggested that this variety was actually old, faded sporophores of variety *pratensis*, which decays slowly and persists for relatively long periods in good condition. Lange (1940) also mentioned var. *pallidus* B. & Br., claiming it to be intermediate between *H. pratensis* and *H. virgineus*, with which it often occurs.

The E.C. Smith Herbarium contains three Nova Scotian collections identified as *H. pratensis* var. *pallidus*, ACAD 3952, ACAD 7122, ACAD 7125. As there are no field data on these collections, it is advisable to adopt the viewpoint of Hesler and Smith (1963) and consider them *H. pratensis* var. *pratensis*. However, the spores of ACAD 3952 measure 7-9.5(11) x 4-6 μm , suggesting that there may indeed be a variety of *H. pratensis* transitional to *H. virgineus*.

Figs 18, 19. *H. murinus*. Fig. 18. H-8337 (K.A. Harrison), X 1.0. Fig 19. ACAD 12120, basidia and spores, redrawn by permission of the National Research Council of Canada from the *Canadian Journal of Botany*, 48, pp. 403-411, 1970.

Subsection MICROSPORI (Sm. & Hes.) Hes. & Sm.
N. Am. Spec. of *Hygrophorus*, p. 82. 1963.

Spores usually shorter than 6.5 μm globose or subglobose; lamellar trama interwoven.

Type species: *H. microsporus* Sm. & Hes.

Series MICROSPORI

Pileus not viscid.

8. *Hygrophorus canescens* Sm. & Hes.

Lloydia 5: 10. 1942.

Camarophyllus canescens (Sm. & Hes.) Singer, Lilloa 22: 148. 1951.

Figs 22, 23.

Basidiocarp: Pileus 2-5 cm broad, convex, the margin lobed; surface subglabrous, or overlain with a thin layer of appressed fibrils, dry, grayish brown (8F3) (ISCC 47) to light purplish gray or dull red (10C3) (ISCC 32); context gray, unchanging; odor and taste not distinctive. Lamellae subdecurrent, dull violet (17E3) (ISCC 228), subdistant. Stipe 4-6 cm long, 5-8 mm thick, tapering toward base, glabrous, pale purplish gray, lighter than pileus, in age nearly white overall; context pale gray, hollow at maturity.

Microscopic Structures: Spores 4-5.5(6) $\times$ 4-5 μm , globose to subglobose, smooth, inamyloid. Basidia 25-35(40) $\times$ 4.5 μm , subclavate, the sterigmata large, to 5 μm long. Pleurocystidia and cheilocystidia absent. Lamellar trama of interwoven hyphae 2-5 μm broad. Pileal cuticle undifferentiated, of interwoven hyphae 2-3 μm broad with numerous erect terminal cells giving appearance of a trichodermium, some terminal cells clavate and 4-5 μm broad at apex, others not expanded. Clamp connections present.

Habit and Habitat: In soil under hemlock, coniferous forest.

Material Studied: ACAD 10451, Aylesford Lake, Kings Co., 9 Aug. 1973; ACAD 10543, Aylesford Lake, Kings Co., 4 Sept. 1973; H-11889 (University of Michigan Herbarium), Aylesford Lake, Kings Co., 1 Sept. 1972.

Remarks: This rare species was first reported from Canada (Grund & Harrison 1974) from specimens collected at Aylesford Lake, and to date has been found only in this area. In color, it resembles *H. rainierensis*, but lacks an odor of green corn. The canescent pileal surface is also distinctive.

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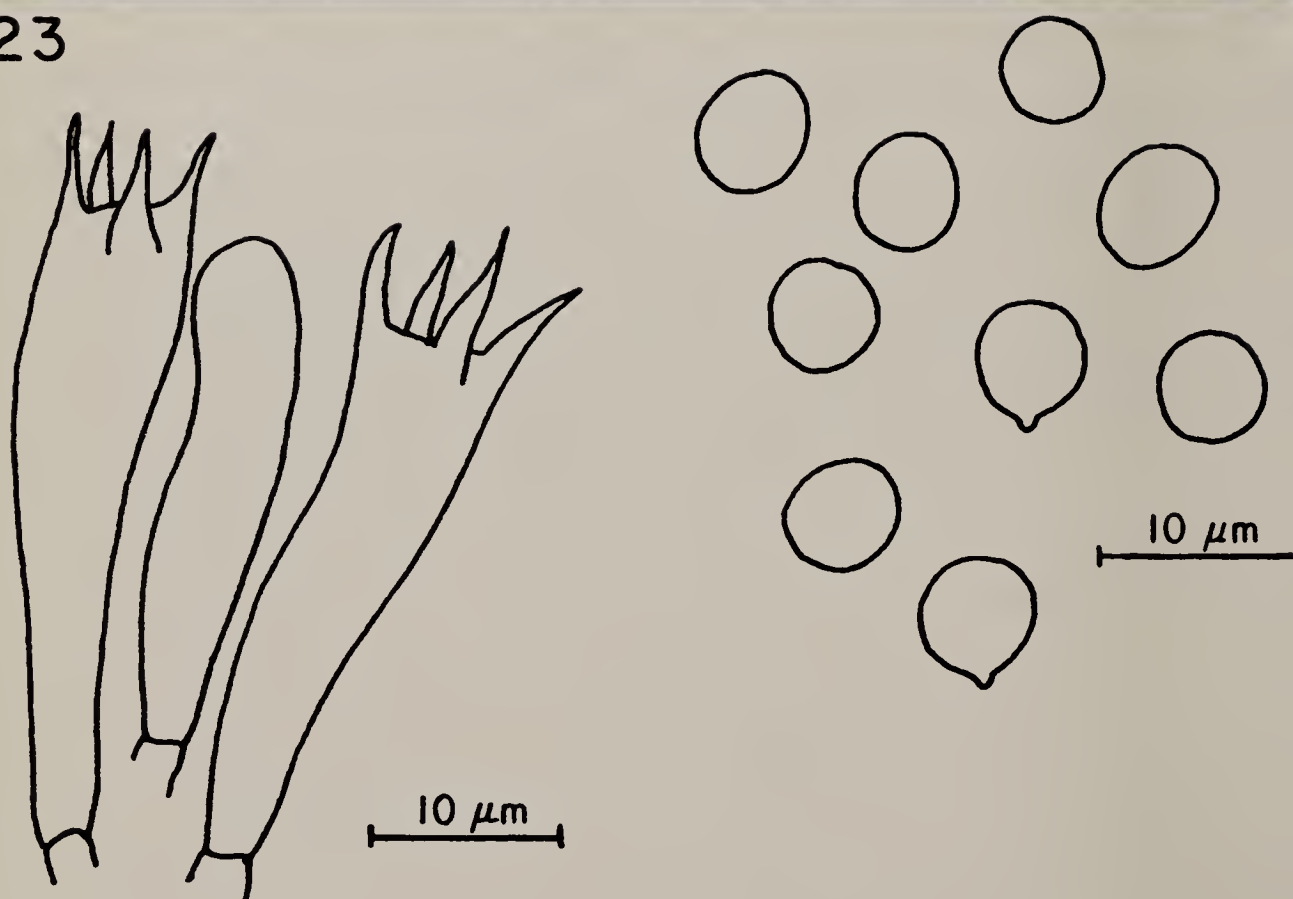


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23



Figs 22, 23. *H. canescens*. Fig 22. ACAD 10543, X 1.0. Fig 23. ACAD 10451, basidia and spores.

Section HYGROTRAMA (Sing.) Hes & Sm.

N. Am. Spec. of *Hygrophorus*, p. 96. 1963.

Lamellar trama moderately interwoven; pileal cuticle hymeniform.

Type species: *H. dennisianus* (Sing.) Hes. & Sm.9. ***Hygrophorus hymenocephalus* Sm. & Hes.**

J. Elisha Mitchell Sci. Soc. 56: 311. 1940.

Camarophyllus hymenocephalus (Sm. & Hes.) M. Lange, Friesia 4: 63. 1950.*Armillariella hymenocephalala* (Sm. & Hes.) Singer, Lilloa 22: 217. 1951.*Hygrotrama hymenocephalum* (Sm. & Hes.) Singer, Sydowia 12: 222. 1959.

Fig 24.

"Pileus 5-20(30) mm broad, convex to hemispheric, margin incurved, often becoming nearly plane, glabrous, hygrophanous, when wet 'snuff brown', 'light pinkish cinnamon', or 'tawny olive', fading to 'clay color' or 'pinkish buff', slowly darker and grayer, sometimes faded specimens 'drab' or 'olive brown' and atomate, finally becoming 'mummy brown', often the margin crenate or lobed. Context thick on the disc, thin elsewhere, waxy, pallid or concolorous with the surface; odor and taste none.

Lamellae broadly adnate, becoming decurrent, concolorous with the pileus when young, nearly so in age or 'hair brown', subdistant to distant, broad, edges pallid and even.

Stipe 2-8 cm long, 2-7 mm thick, concolorous with the pileus, darkening in age, finally becoming 'mummy brown', equal or tapering downward, fragile, terete or compressed, the apex canescent at first, elsewhere glabrous, solid becoming hollow.

Spores 4-6 x 4-5 μ , globose to subglobose, at times short-ellipsoid, often more or less flat-sided, smooth, pale yellowish in Melzer's reagent. Basidia 34-50(64) x 5-8 μ , 2- and 4-spored. Pleurocystidia and cheilocystidia not differentiated. Gill trama of interwoven hyphae 4-10 (16) μ broad, the hymenium appearing as a blackish line in sections of old material. Pileus with an epicutis of an irregular palisade of inflated cells (30)40-85 x (10)14-22(30) μ —an epithelium. Pileus trama of subparallel hyphae, radially disposed. No clamp connections." (Hesler & Smith 1963).

Habit and Habitat: "Gregarious to scattered on soil and decaying logs . . . in mixed and coniferous woods . . ." (Hesler & Smith 1963).

Remarks: J. Walton Groves collected this species at Aldershot, Kings Co., in 1952 (K.A. Harrison, pers. comm.). It has not been found since then in Nova Scotia.

10. ***Hygrophorus subfuscescens* Sm. & Hes. var. *subfuscescens***

Sydowia 8: 317. 1954.

Figs 25, 26.

Basidiocarp: Pileus 0.6-2 cm broad, convex, margins nearly inrolled young, becoming broadly rounded and crenate at maturity, glabrous, moist to subviscid, hygrophanous, at first champagne (4B4) (ISCC 90), becoming honey yellow (4D6) (ISCC 95) to orange-white (5A2) (ISCC 73), and finally sunburn (6D5) (ISCC 57); context grayish brown to pallid, brittle; odor not distinctive, taste faintly subnauseous. Lamellae decurrent, clay (5D5) (ISCC 76), distant. Stipe 2-4 cm long, 2-3 mm thick, glabrous, pale yellow (ISCC 89).

Microscopic Structures: Spores 5-6 x 4.5-5 μ m, subglobose to globose, smooth, inamyloid. Basidia 35-40 x 5-7 μ m, clavate to subcylindric, 4-spored. Pleurocystidia and cheilocystidia absent. Pileal cuticle hymeniform, of clavate to nearly

subglobose, thin-walled cells 30-40 x 15-20 μm , hyaline to light brown in KOH. Lamellar trama moderately interwoven. Clamp connections not observed.

Habit and Habitat: On black muck in swampy areas of mixed woods.

Material Studied: ACAD 10542, Aylesford Lake, Kings Co., 4 Sept. 1973.

Remarks: This rare *Hygrophorus* has been collected only once in Nova Scotia. The distant lamellae, yellow glabrous stipe, hymeniform cuticle, and small globose spores are distinctive for this species. Hesler and Smith (1963) also mentioned the habitat of black muck; thus, the substratum also may be characteristic.

Section HYGROPHORUS

Lamellar trama divergent.

Type species: *H. eburneus* Fr.

Subsection HYGROPHORUS

Stipe with a gelatinous outer veil almost to apex.

Series CHRYSODONTINI (Sing.) Hes. & Sm.

N. Am. Spec. of *Hygrophorus*, p. 249. 1963.

Sporocarp white with yellow granules on stipe apex and pileus margin.

Type species: *H. chrysodon* (Fr.) Fr.

44 *Hygrophorus chrysodon* (Fr.) Fr.

Epicr. Myc., p. 320. 1838.

Agaricus chrysodon Fr., Syst. Myc. 1: 32. 1821.

Limacium chrysodon (Fr.) Kummer, Führ. in Pilzk., p. 118. 1871.

Figs 27, 28.

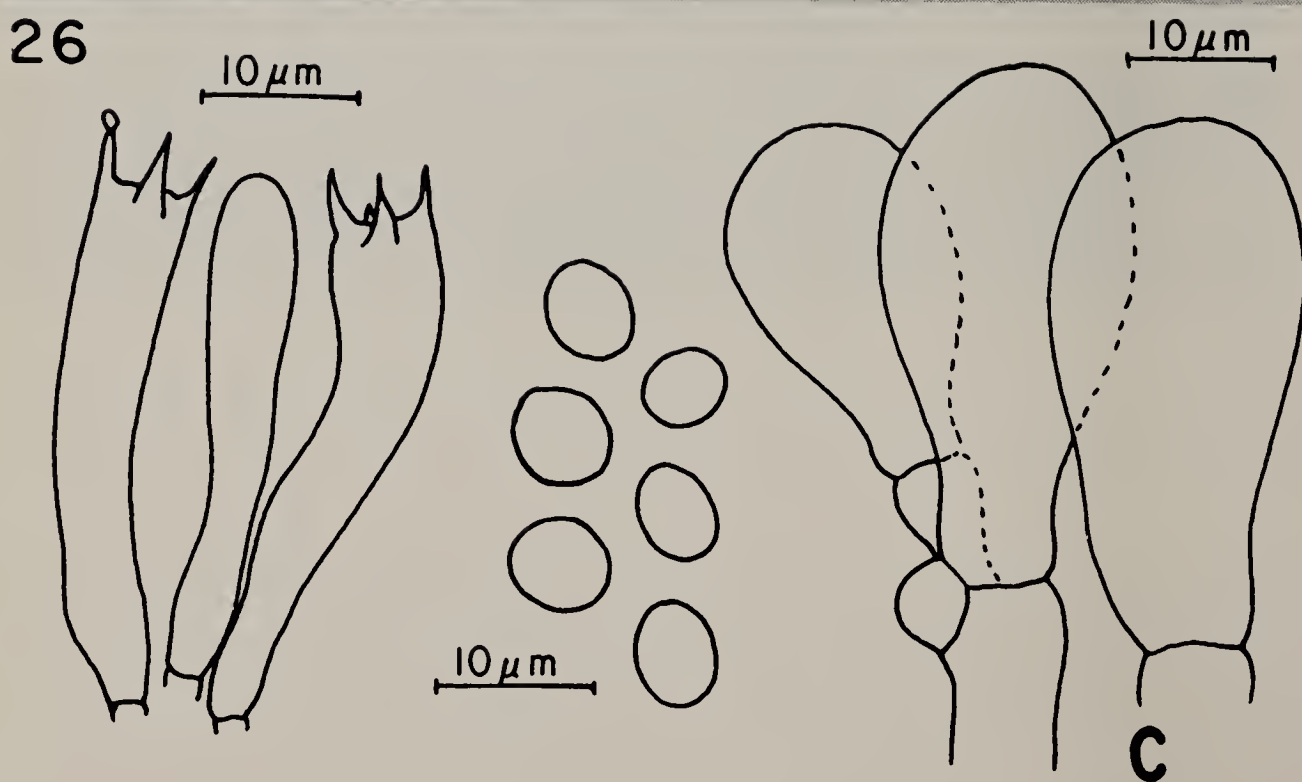
Basidiocarp: Pileus 1.5-4 cm broad, convex, expanding, margin incurved when young, viscid, soon dry, margin shaggy-tomentose young, pallid yellow-pruinose overall at first, later white and glabrous, with superficial yellow floccules and granules on margin, sometimes remaining yellow-pruinose on disc; context thin to moderately thick (1.5-3 mm on disc), white, spongy; odor and taste not distinctive. Lamellae short-decurrent, white, becoming pale creamy yellow or pallid tan in age, subdistant to rather close, moderately broad (2-4 mm), thin, edges even. Stipe 3.5-8 cm long, 5-7.5 mm thick at apex, whitish, with yellow floccules at apex, usually flushed yellowish over the middle, the yellow fibrils darkening in KOH and the white tissue yellowing, white within, apex dry, lower part briefly viscid from a thin, gelatinous veil, pruinose to glabrous beneath the gluten, annulus obsolete; subequal to terete, stuffed.

Microscopic Structures: Spores (7)7.5-11.5 x (3.5)4-6 μm , ellipsoidal, smooth, in-amyloid. Basidia 32-44 x 6-8(10.5) μm , narrowly clavate, 4-spored, the sterigmata stout and prominent, to 6 μm long. Pleurocystidia and cheilocystidia absent. Gill trama of divergent hyphae 2.5-10 μm broad. Cuticle a thin ixocutis, 30-65(138) μm deep, of gelatinous, generally radial, repent to erect hyphae 1.7-3.5(6) μm broad, topped by scattered masses of yellowish hyphae and amorphous matter. Pileal trama of radial, slightly interwoven hyphae 3.5-17.5 μm broad; hypodermium absent. Clamp connections present in the cuticle, gill trama, and pileal trama.

Habit and Habitat: Solitary to subcespitose in coniferous woods. Rare.



Fig 24. *H. hymenocephalus*. H-10383 (K.A. Harrison), X 2.5.



Figs 25, 26. *H. subfuscescens* var. *subfuscescens*. Fig 25. ACAD 10542, X 1.25. Fig 26. ACAD 10542, basidia, spores, and hymeniform cuticular cells (C) of the pileus.

Material Studied: ACAD 12204, Washabuck, Victoria Co., 25 Sept. 1968; ACAD 12238, near Denver, Guysborough Co., 14 Oct. 1968.

Remarks: *Hygrophorus chrysodon* is easily distinguished by the yellow granules on the white pileus margin and stipe apex. Like most local species of subsection *Hygrophorus*, it soon loses its viscid stipe veil, but sectioning will reveal gelatinous remnants.

Series HYGROPHORUS

Sporocarp entirely white to whitish before maturity; lamellar trama divergent; stipe with a gelatinous outer veil.

12 *Hygrophorus eburneus* (Fr.) Fr.

Epicr. Myc., p. 321. 1838.

Agaricus eburneus Fr., Syst. Myc. 1: 33. 1821.

Limacium eburneum (Fr.) Kummer, Führ. in Pilzk., p. 119. 1871.

Figs 29, 30.

Basidiocarp: Pileus 2-5.5 cm broad, obtuse or convex young, later plane, the disc at times depressed, viscid fresh, soon resinous to dry, glabrous, white, tending to very pale yellowish on disc; context thick (3-5 mm on disc), white, compact; odor and taste not distinctive. Lamellae adnate young, then uncinatate and finally decurrent, creamy white, drying pale ochraceous, subdistant, moderately broad (2-6 mm), edges even. Stipe 4.5-6 cm long, 4-9 mm thick at apex, white, faintly tomentose at apex, viscid below, soon dry and innately fibrillose, equal or narrowed upwards, white within, solid or stuffed.

Microscopic Structures: Spores (6)6.5-8.5(10) x 4-6 μ m, short-elliptical, occasionally tending to subglobose, or obovate, or broadened at the apicular end, smooth, inamyloid. Basidia (23)30-60 x 5-11 μ m, narrowly clavate, rarely stout, 4-spored, sometimes 2-spored as well, the sterigmata large and prominent, up to 8 μ m long, mostly about 6 μ m. Pleurocystidia and cheilocystidia absent. Gill trama of divergent hyphae 2.5-21 μ m broad. Cuticle an ixocutis, 60-140 μ m deep, the hyphae 2.3-4.5 μ m broad, gelatinous, tangled, generally repent with several to many ascending free ends. Pileal trama radial and subparallel; hypodermium absent. Stipe surface with a few scattered, subgelatinized hyphae, but no definite gelatinous sheath persisting after maturation or drying. Clamp connections present on the hyphae of the cuticle, gill trama, pileal trama, stipe surface and context.

Habit and Habitat: Gregarious in moss (*Pleurozium* sp.) under hemlock.

Material Studied: ACAD 310, ravine, Agriculture Experimental Station, Kentville, Kings Co., 9 Sept. 1933; ACAD 1408, Agriculture Experimental Station, Kentville, Kings Co., 15 Oct. 1951; ACAD 12107, ravine, Agriculture Experimental Station, Kentville, Kings Co., 4 Oct. 1967.

Remarks: The gelatinous veil covering the stipe is thin and evanescent, and the apparently dry stipe will lead to identification of the mushroom as *H. piceae* Kühn. & Romagn. or *H. sordidus* Pk. of Series *Clitocyboides* Hes. & Sm. in Subsection *Camarophylli*. Sectioning of the stipe is very important if the presence of a gelatinous veil is suspected. In the field, this striking white fungus may be mistaken for *H. niveus*, *H. borealis* f. *borealis*, or even *H. virgineus* if the pileal gluten has dried. Examination of the lamellar trama will easily separate it from these three members of Section *Camarophylloopsis*.

Groves (1962), Hesler and Smith (1963), and Wakefield and Dennis (1950) all

described the pileus as pure white. The yellow tinge apparent in our material also appears in color illustrations of *H. eburneus* by Michael and Schulz (1927) and Poelt and Jahn (1963), and may have been occasioned by age or partial drying of the sporocarps.

Murrill (1916) discussed *H. eburneus* under synonymy with *H. jozzolus* (Scop.) Murrill.

Series AUREI (Bataille) Hes. & Sm.

N. Am. Spec. of *Hygrophorus*, p. 273, 1963.

Pileus yellow, orange, or red, at least on disc; lamellar trama divergent; stipe with gelatinous outer veil.

Type species: *H. aureus* Arrh. in Fr.

13. *Hygrophorus speciosus* Pk. var. *speciosus*

N. Y. State Mus. Ann. Rep. 29: 43. 1878.

Figs 31, 32.

Basidiocarp: Pileus 2.5 cm broad, "convex, expanding, at times umbonate, . . ." (p. 277, Hesler & Smith 1963), at length depressed, viscid, soon dry and glossy, obscurely virgate near disc, red orange (ISCC 34) at first, fading to yellow-orange on margin (ISCC 48, 66); context rather thin (1.5 mm on disc in depressed pileus), whitish to pallid yellowish, soft; odor and taste not distinctive. Lamellae adnate to decurrent, uniformly yellowish-white, subdistant, moderately broad (2.5 mm), edges even. Stipe 3.5 cm long, 4 mm thick at apex, whitish, sheathed over lower two-thirds by a thin, evanescent gelatinous veil which dries in yellow streaks and terminates above in a narrow, tawny, gelatinous, fugacious ring, pruinose to fibrillose above, subequal, slightly enlarged downwards, pallid yellow within, solid.

Microscopic Structures: Spores 7.5-10.5 x 4.5-6 μm , ellipsoidal, occasionally narrowed toward the apiculus, smooth, inamyloid. Basidia 37-57 x 7-10 μm , long-clavate, 4-spored, the sterigmata up to 6 μm long. Pleurocystidia and cheilocystidia absent. Gill trama of divergent hyphae 3.5-6(10) μm broad. Cuticle a narrow ixotrichodermium of gelatinous, more or less erect hyphae 3-6 μm broad, arising from a substratum of yellowish, repent hyphae, in places remaining repent after drying and then forming an ixocutis. Pileal trama radial and slightly interwoven; hypodermium absent. Clamp connections present in the cuticle, gill trama, and pileal trama.

Habit and Habitat: Solitary among mosses under larch in spruce-larch forest.

Material Studied: ACAD 12233, River Head, Queens Co., 11 Oct. 1968.

Remarks: This species is evidently rare in our area. The single, small but mature carpophore on which the above description is largely based, is the only specimen of *H. speciosus* taken in Nova Scotia from 1968 to date, despite considerable collecting in habitats with larch.

Hygrophorus speciosus var. *speciosus* is one of several closely related and nearly identical fungi in the *H. aureus*-*H. speciosus* group. The only other member of this complex reported in North America is *H. speciosus* var. *kauffmanii* Hes. & Sm.

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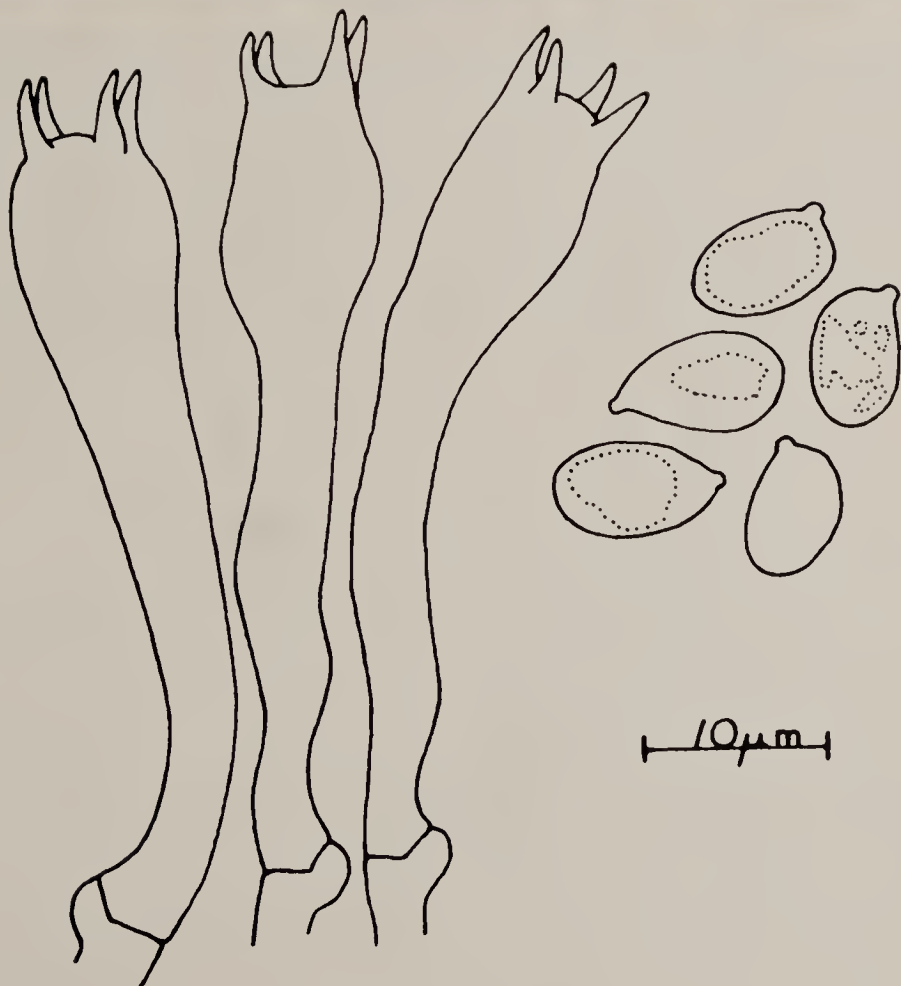


Figs 29, 30. *H. eburneus*. Fig 29. Courtesy of K.A. Harrison, X .8. Fig 30. ACAD 12107, basidia and spores.

31



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Figs 31, 32. *H. speciosus* var. *speciosus*. Fig 31. Smith 58294, X .65. Fig 32. ACAD 12233, basidia and spores.

33



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Figs 33, 34. *H. flavodiscus*. Fig 33. ACAD 12274, X .75. Fig 34. ACAD 12274, basidia and spores, redrawn by permission of the National Research Council of Canada from the *Canadian Journal of Botany*, 48, pp. 403-411. 1970.

(formerly *H. coloratus* Pk.). It differs from the typical variety in the thin, fibrillose inner veil apparent on the stipes of young sporophores, and in being associated with other conifers besides larch (Hesler & Smith 1963; Peck 1908). However, in the original description of *H. coloratus*, Peck (1908) suggested that this and other members of the complex may be a single, variable species.

The E.C. Smith herbarium contains a single collection of *H. aureus* (ACAD 5263, Gore, Hants Co., 1963), found under larch. As *H. aureus* is a European species associated with hardwoods, the Nova Scotian collection is probably *H. speciosus* var. *speciosus*.

14 *Hygrophorus flavodiscus* Frost apud Pk.

N. Y. State Mus. Ann. Rep. 35: 134. 1884.

Figs 33, 34.

Basidiocarp: Pileus 2.5-5.5 cm broad, hemispheric young with involute margin, becoming broadly convex, sometimes subumbonate, finally planoconvex to depressed, glutinous when moist, the gluten thick, frequently granular and rubbery, glabrous beneath, uniformly butter yellow (4A5) (ISCC 86) or maize yellow (4A6) (ISCC 83) in buttons, lightening to pallid yellow on the margin as the pileus expands, becoming streaked or dotted ochraceous yellow on drying; context thick (3-10 mm on disc), soft, white; odor and taste mild, not distinctive. Lamellae short-decurrent, at times adnate, very pale yellowish white, subdistant to rather close, moderately broad (3-4 mm) and thin, edges even. Stipe 4-9 cm long, 7-16 mm thick at apex, sheathed almost to apex by a scant, white, fibrillose inner veil and a copious, yellowish, glutinous outer veil, white and tomentose to silky above a rudimentary, evanescent, superior annulus, in age whitish and streaked and laved below with yellow veil fragments, equal, straight or curved; context white, pale greenish in KOH, solid.

Microscopic Structures: Spores 6-8.5 x 3.5-5 μm , short-elliptical to obovate, smooth, inamyloid. Basidia 31-55 x 6.5-8 μm , slender, clavate, sometimes flexuous, mostly 2- and 4-spored, rarely 1-spored, the sterigmata stout, up to 6 μm long. Pleurocystidia and cheilocystidia absent. Gill trama of divergent hyphae 4-20 μm broad. Cuticle a very thick (450-1150 μm) ixotrichodermium of narrow, branched, gelatinous hyphae, not forming a palisade. Pileal trama radial and slightly interwoven; hypodermium none. Clamp connections present in the cuticle, gill trama, and pileal trama.

Habit and Habitat: Gregarious in pine woods.

Material Studied: ACAD 12274, Centreville, Kings Co., 27 Oct. 1968.

Remarks: The copious gluten covering the pileus and stipe is almost entirely responsible for the conspicuous yellow hues of fresh material. The colors reported above do not agree with those given by Peck (1907), Murrill (1916), Kauffman (1918), or Hesler and Smith (1963), all of whom described a white pileus with a yellow or red-yellow disc, and a white stipe plus or minus yellow stains. However, Bigelow (1959) reported *H. flavodiscus* as even darker yellow overall than the Nova Scotian specimens. Color in *H. flavodiscus* is intensified considerably by drying (Hesler and Smith 1963, Smith and Hesler 1939), but the bright colors of ACAD 12274 are not due to desiccation as the specimens were in prime condition when collected. Rather, the greater thickness of gluten probably accounts for the discrepancy; if the gelatinous layers in ACAD 12274 were as thin as indicated by Hesler and Smith (1963) for this species (180-350 μm), the colors then would be similar to those described by Peck and others.

A second difference in ACAD 12274 is the absence of pinkish tints on the gills, in all stages of development. Whereas Peck, the author of the species, described the

gills as "... sometimes with a flesh-colored tint" (Peck 1907), we surmise the feature is not a critical one.

The double veil of the stipe is discernible only in the button stage, in which a thin coating of white fibrils lines the inner surface of the gluten extending between the stipe and pileus margin.

Spore size is a fairly definitive feature. No other macroscopically similar species has spores this small. The presence of 2-spored basidia in ACAD 12274 does not appear to alter spore size from the typical range for *H. flavodiscus*.

Collection ACAD 12271 (under pine, ravine, Agriculture Experimental Station, Kentville, Kings Co., 15 Oct. 1968) is macroscopically identical with the material described above. Microscopically, it differs in having spores $(6)6.5-10.5(11.5) \times 3.5-7 \mu\text{m}$, although the basidia are still typically 2- and 4-spored as in ACAD 12274. This variant is intermediate between *H. flavodiscus* and the similar but larger-spored *H. gliocyclus*.

15. *Hygrophorus gliocyclus* Fr.

Monogr. Hymen. Suec. 2: 311. 1863.

Figs 35, 36.

Basidiocarp: Pileus 3-9 cm broad, convex and expanding, or broadly rounded at margins, subumbonate, glabrous, glutinous, gluten separable; light brown, chamois color (ISCC 76) to buff (ISCC 73); context solid and thick under umbo, becoming thin at margin, odor and taste not distinctive. Lamellae adnate to decurrent at maturity, subdistant, yellowish buff (ISCC 90). Stipe 2-6 cm long, 6-15 mm thick, equal and abruptly tapered at base, surface with a glutinous sheath that forms an annulus near the apex, above the annulus floccose or minutely fibrillose, apex white, remainder chamois color (ISCC 76) under the hyaline gluten; context solid, pallid.

Microscopic Structures: Spores $8-10(12.5) \times 4-5 \mu\text{m}$, elliptical, in profile inequilateral or approaching subfusiform, smooth, inamyloid. Basidia $35-44 \times 7.5-9.5 \mu\text{m}$, narrowly clavate, mostly 4-spored, at times 2-spored also, the sterigmata slender, up to $6 \mu\text{m}$ long. Pleurocystidia and cheilocystidia absent. Gill trama of narrow to inflated divergent hyphae $3-22 \mu\text{m}$ broad. Cuticle an ixotrichodermium about $170 \mu\text{m}$ thick, sometimes rehydrating as an ixocutis, the hyphae gelatinous, $2.3-5.5 \mu\text{m}$ broad, erect to repent, tangled. Pileal trama of radial, subparallel hyphae similar to those of gill trama; hypodermium absent. Stipe surface with a definite zone, $100-130 \mu\text{m}$ thick, of loose, repent, longitudinal or tangled gelatinous hyphae similar to those of cuticle. Clamp connections present in the cuticle, gill and pileal tramas, stipe veil, and stipe context.

Habit and Habitat: Gregarious in coniferous woods. Rare.

Material Studied: ACAD 292, Annapolis Royal, Annapolis Co., 15 Oct. 1932.

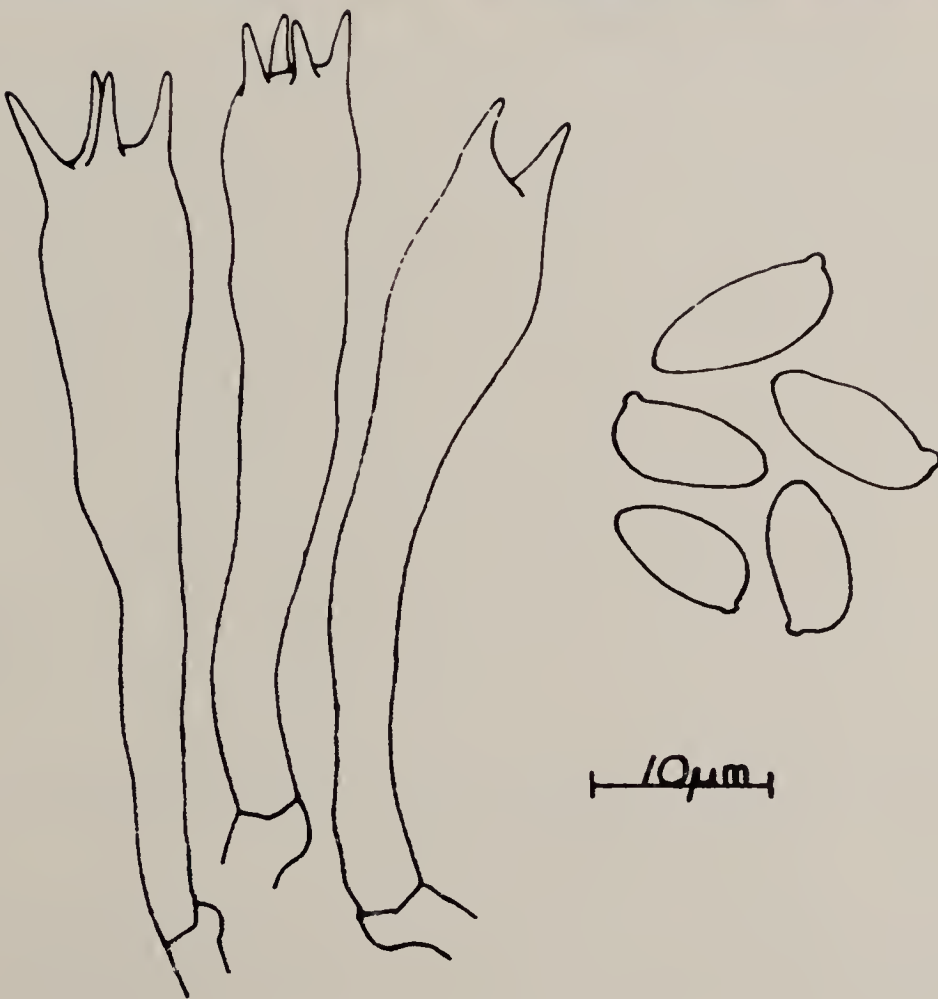
Remarks: The presence of this species in Nova Scotia is questionable. We did not encounter it in the field, and the single collection of it in the E.C. Smith herbarium bears the note: "A. H. Smith says 'This may be a slender specimen of *H. gliocyclus* Fr.' ". The microscopic data seem to indicate that Smith is correct.

Hygrophorus gliocyclus is macroscopically very similar to *H. flavodiscus* as we know it, with its butterscotch-yellow pileus, its whitish lamellae, and its copious gluten. However, stipe coloration in *H. gliocyclus* is borne by hyphae beneath hyaline gluten, while in *H. flavodiscus* the color is carried in the gelatinous veil itself. In the absence of fresh specimens with well-developed stipe veils, spore size is the only reliable feature distinguishing the two species.

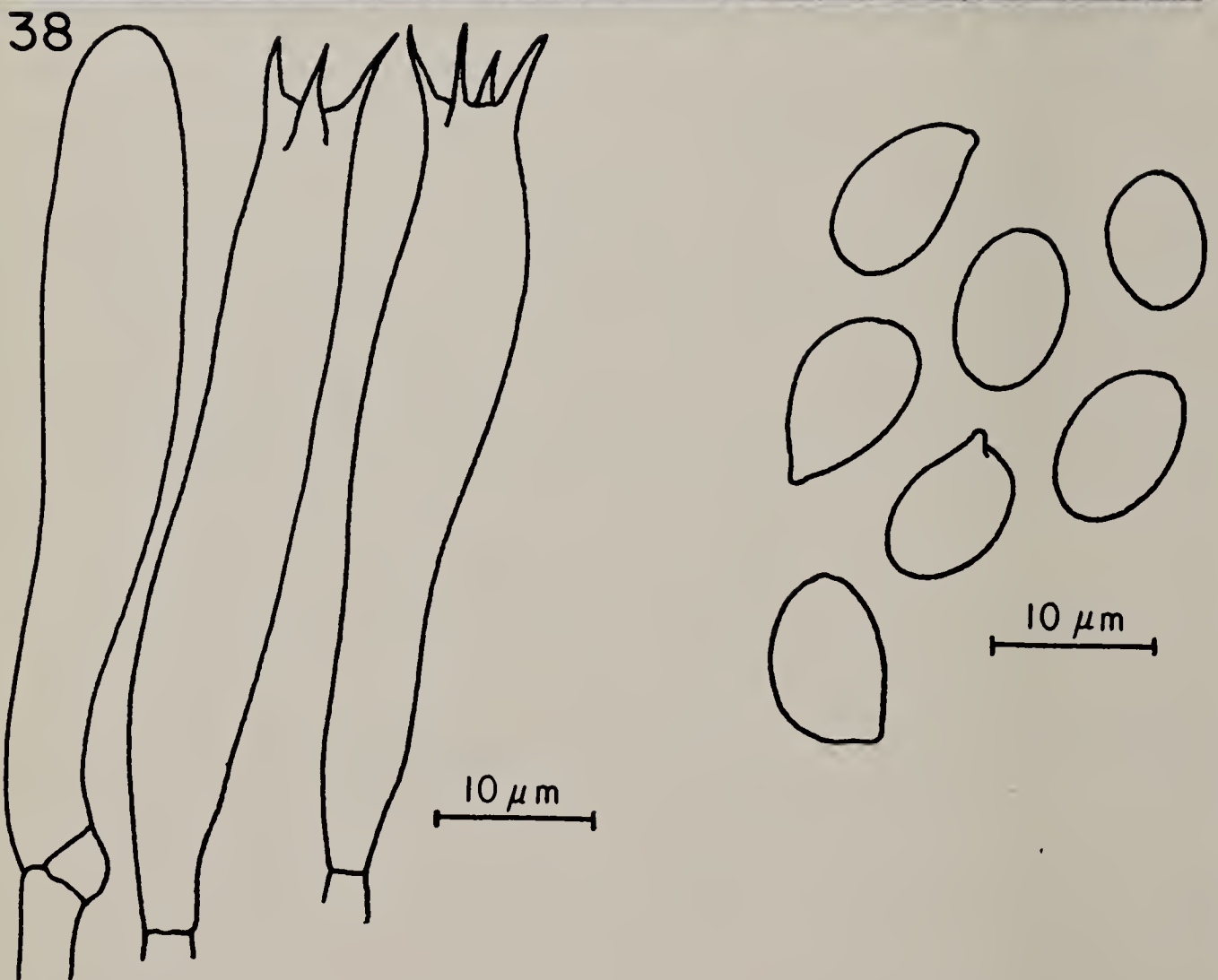
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Figs 35, 36. *H. gliocyclus*. Fig 35. Smith 65644, X .75. Fig 36. ACAD 292, basidia and spores.



Figs 37, 38. *H. hypothejus*. Fig 37. DG 1670 (D.W. Grund), X 1.0. Fig 38. ACAD 5459, basidiole, basidia, and spores.

16. **Hygrophorus hypothejus (Fr.) Fr.**

Epicr. Myc., p. 324. 1838.

Agaricus hypothejus Fr., Syst. Myc. 1: 35. 1821.*Hydrocybe arenicola* Murr. Mycologia 4: 208. 1912.*Hygrophorus subpustulatus* (Murr.) Murr. Mycologia 4: 210. 1912.*Limacium hypothejum* (Fr. ex Fr.) Kummer, Führ. in Pilzk., p. 119. 1871.

Figs 37, 38.

Basidiocarp: Pileus 2-8 cm broad, convex becoming plane, umbonate, viscid, glabrous or with appressed fibrils at margin, hair brown (5E4) (ISCC 80) on disc, shading to pastel green (30A4) (ISCC 121) at margin, in old age becoming yellowish with occasional development of reddish shades; context thin, pallid, becoming pale yellow under pellicle; odor and taste not distinctive. Lamellae decurrent, pale yellow to pale green, mostly distant. Stipe 7-16 cm long, 5-12 mm thick, annulate, silky fibrillose and pale yellow (ISCC 104) above annulus, glutinous to viscid with olive brown (ISCC 95) to orange shades below; context pale yellowish, firm, solid.

Microscopic Structures: Spores 8-10(12) x 5-7 μ m, ellipsoid, smooth, inamyloid. Basidia 40-50 x 4-8 μ m, cylindric to subcylindric, 4-spored. Pleurocystidia and cheilocystidia absent. Pileal surface a viscid pellicle 250-300 μ m thick, of tangled gelatinous hyphae 3-5 μ m thick, with numerous clamp connections. Lamellar trama divergent from a mediostrate of parallel hyphae. Pileal trama of interwoven, radially oriented hyphae.

Habit and Habitat: Gregarious under *Pinus banksiana* Lamb.

Material Studied: H-12777 (University of Michigan Herbarium), Isle Madame, Richmond Co., 14 Oct. 1977; ACAD 5459, Priest Lake, Idaho, U.S.A.

Remarks: This species has been collected 3 times in Nova Scotia—twice on Isle Madame, and once in Cape Breton Highlands National Park. However, the specimens are not deposited locally, and thus the microscopic details illustrated are taken from the Idaho collection cited above. As we are familiar with *H. hypothejus* from collections (DWG's) made in the Pacific Northwest of the United States, we recognize the presence of this mushroom in Nova Scotia. Its habit of growing under two-needle pines is characteristic.

Series OLIVACEOUMBRINI (Fr.) Hes. & Sm.

N. Am. Spec. of *Hygrophorus*, p. 283. 1963.

Pileus umber, olive brown, gray-brown, or gray, at least on the disc; lamellar trama divergent; stipe with gelatinous outer veil.

Type species: *H. olivaceoalbus* (Fr.) Fr.

17. **Hygrophorus olivaceoalbus (Fr.) Fr. var. olivaceoalbus**

Epicr. Myc., p. 324. 1838.

Agaricus olivaceoalbus Fr., Syst. Myc. 1: 35. 1821.*Limacium olivaceoalbum* (Fr. ex Fr.) Kummer, Führ. in Pilzk., p. 119. 1871.

Figs 39, 40.

Basidiocarp: Pileus 2-5 cm broad, convex to obtuse young, expanding, at times subumbonate, finally plane with a low to pronounced umbo or with uplifted margin,

glutinous to viscid when fresh, drying appressed fibrillose, virgate when expanded, blackish brown on disc, paling to tobacco brown (5F6), (ISCC 78), mustard brown (5E6) (ISCC 77), hair brown (5E4) (ISCC 80), or dark blond (5D4) (ISCC 77) on margin; context moderately thick (2-7 mm on disc), white, sometimes tinged brownish under the pellicle, soft, compact; odor and taste not distinctive. Lamellae adnate and uncinata, becoming short-decurrent, white, subdistant, thickish, moderately broad (2.5-5.5 mm), occasionally intervenose or forked near margin. Stipe 3.5-7 cm long, 6-13 mm thick at apex, sheathed almost to apex by two veils: (1) the outer veil gelatinous, soon disappearing, leaving a superior, thin, brown, glutinous to membranous, fugacious ring; (2) the inner veil of appressed fuscous to medium brown fibrils similar to those of pileus, often breaking into ragged, encircling zones or patches as the stipe elongates; apex dry, white, silky to pruinose; white within, equal or enlarged downwards, at times slightly expanded at annular zone, solid.

Microscopic Structures: Spores (8.5)9.5-12.5(14.5) $\times$ 4.5-8 μ m, ellipsoidal, smooth, inamyloid. Basidia 48-70(78) $\times$ 6.5-13.5 μ m, narrowly clavate, 4-spored, the sterigmata stout and prominent, up to 10(14.5) μ m long. Pleurocystidia and cheilocystidia absent. Gill trama divergent from a central strand, the hyphae slender to inflated, 3.5-24.5 μ m broad. Cuticle an ixocutis 70-500 μ m thick, the hyphae 2.5-6 μ m broad, light brown, gelatinous, radial and repent or loosely interwoven, branched, arising from a compact layer of brownish hyphae transitional to the context. Pileal trama of radial, slightly interwoven hyphae similar to the gill tramal hyphae; hypodermium absent. Clamp connections present in the cuticle, gill trama, and pileal trama.

Habit and Habitat: Scattered to gregarious in moss or coniferous litter in spruce or hemlock woods. Frequent.

Material Studied: ACAD 12110, Wolfville, Kings Co., 13 Oct. 1967; ACAD 12210, Kentville Ravine, Kings Co., 30 Sept. 1968; ACAD 12261, Aspen, Guysborough Co., 14 Oct. 1968; ACAD 12282, North Mountain, Kings Co., 29 Oct. 1968.

Remarks: This species is distinguished by its viscid, brown pileus and the brown stipe sheath. *H. inocybiformis* bears a superficial resemblance but has a dry pileus and larger spores.

The transience of the gelatinous veil on the stipe presents problems in identification, as there are similar species with dry stipes in Subsection *Camarophylli*. Examination of sporophores in all stages of development showed that in local material, there is a thin, viscid coating at first, but this veil fragments and disappears as the stipe elongates, leaving only a narrow, glutinous to moist ring. In old sporophores, even this rudimentary annulus sometimes vanishes.

In keeping with the present criteria of the variety (Hesler and Smith, 1963), we are including only 4-spored forms with spores about 9-12 μ m long in our description of var. *olivaceoalbus*. Forms with 2- and 3-spored basidia and larger spores are interpreted as the *Hygrophorus olivaceoalbus* complex.

18. *Hygrophorus fuliginus* Frost apud Pk.

N.Y. State Mus. Ann. Rep. 35: 134. 1884.

Figs 41, 42.

Basidiocarp: Pileus 4-11 cm broad, convex expanding to plane at maturity; surface glabrous, overlain with a hyaline mantle of gluten, blackish brown (ISCC 62) to dark olive brown (ISCC 96), becoming lighter at margins, sometimes drying a lighter olive brown (ISCC 91); context firm, white; taste and odor not distinctive. Lamellae adnate to subdecurrent, pallid, subdistant at maturity. Stipe 4-9 cm long, 8-20 mm thick, equal or tapering at base, white, glabrous to minutely fibrillose at apex, tomentose below, and overlain by a coat of hyaline gluten; context solid and white.

39



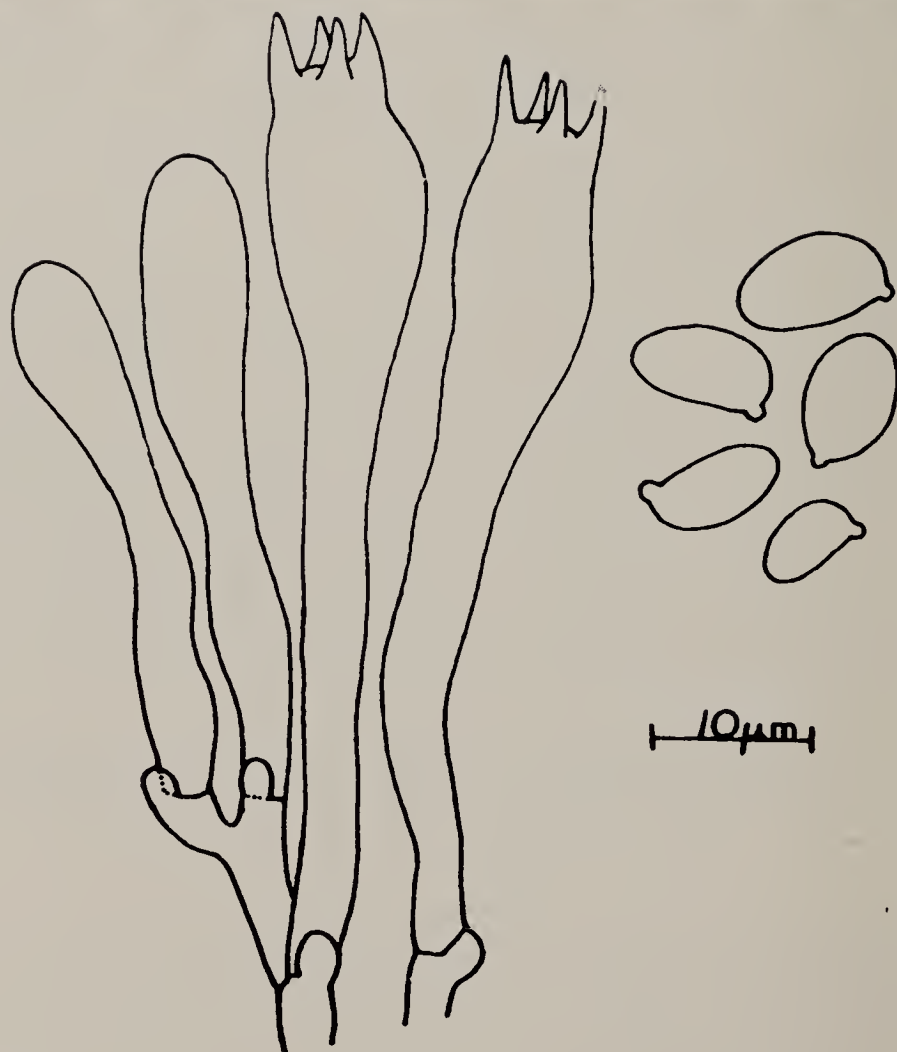
40



Figs 39, 40. *H. olivaceoalbus* var. *olivaceoalbus*. Fig 39. ACAD 12282, X 1.0. Fig 40. ACAD 12210, basidia and spores.



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Figs 41, 42. *H. fuligineus*. Fig 41. Smith 33952, X .8. Fig 42. ACAD 2630, basidioles, basidia, and spores.

Microscopic Structures: Spores (7)8-9.5 x (4)4.5-6 μm , short-elliptical, smooth, in-amyloid. Basidia 42-58 x 8-9.5 μm , narrowly clavate, 4-spored, the sterigmata up to 4.5 μm long. Pleurocystidia and cheilocystidia absent. Gill trama divergent from a colorless to pallid yellowish central strand, the hyphae 3.5-9.5 μm broad, rather sparingly septate. Cuticle an ixotrichodermium 345-520 μm deep, the hyphae 2.3-4.5 μm broad, gelatinous, generally erect and tangled, almost forming a palisade, colorless to very pale yellow as revived in KOH, merging beneath with yellow-brown hyphae. Pileal trama of radial, subparallel to rather interwoven hyphae 4.5-19 μm broad. Stipe surface covered with tangled, roughly longitudinal, gelatinous hyphae 2.3-6 μm broad, merging with the context hyphae; no discrete inner fibrillose veil. Clamp connections present in the cuticle, gill and pileal tramas, stipe veil, and stipe context.

Habit and Habitat: "On soil, in conifer and mixed woods, . . ." (Hesler & Smith 1963).

Material Studied: ACAD 2630, Aldershot, Kings Co., 10 Sept. 1953.

Remarks: *Hygrophorus fuliginus* is distinguished by its viscid, blackish to grayish brown pileus and its viscid, whitish stipe. The stipe gluten is relatively persistent in contrast with that of most other species in Subsection *Hygrophorus*. Once the gluten dries, old, faded sporophores resemble *H. agathosmus* but lack an amygdaline odor.

Bresadola (1928) considered *H. fuliginus* conspecific with *H. limacinus* Fr., a paler brown species with larger spores (Hesler and Smith, 1963). Bresadola's description of *H. limacinus* could apply to *H. fuliginus*, but his illustration does not represent the North American concept of the latter species.

Murrill (1916) reduced *H. fuliginus* to synonymy with *H. hypothejus*. Most mycologists separate these two species on the basis of the yellow lamellae and the pileal color changes in *H. hypothejus*.

Hesler and Smith (1963) mentioned a well-defined hypodermium of brownish, interwoven hyphae. This could be the yellow-brown subcuticular hyphae interpreted in our description as part of the colored cuticle.

19 *Hygrophorus tephroleucus* (Fr.) Fr. var. *tephroleucus*.

Epicr. Myc., p. 325. 1838.

Agaricus tephroleucus Fr., Syst. Myc. 1: 34. 1821.

Limacium tephroleucum (Fr.) Kummer, Führ. in Pilzk., p. 119. 1871.

Figs 43, 44.

Basidiocarp: Pileus 0.5-3 cm broad, hemispheric with involute margin when young, expanding convex to planoconvex or convex-depressed, at times subumbonate or with a small, pointed umbo, viscid to glutinous when moist, glabrous to appressed fibrillose beneath the gluten, disc at times appressed floccose, margin often becoming obscurely crenate, beaver (5F4) (ISCC 59), hair brown (5E4) (ISCC 80), nougat (5D3) (ISCC 60), sallow (4D3) (ISCC 91), or beige (4C3) (ISCC 90), darker on disc, occasionally zonate; context thin (1-3 mm on disc), white or tinged cinereous under pelticle, soft; odor and taste not distinctive. Lamellae adnate to subdecurrent, at times uncinuate, white, subdistant, thickish, moderately broad (1-5 mm), rarely forked near the stipe, edges even or eroded. Stipe 2-6 cm long, 2-7 mm thick at apex, at first white and pruinose to fibrillose overall, later with minute cinereous apical squamules and basal fibrils, finally minutely fuscous-squamulose over entire length except for embedded portion of base, the ornamentation coarser above, base slightly viscid in young specimens, very soon dry, equal or tapering downward, rarely narrowed above, sometimes flexuous, white within, stuffed or solid.

Microscopic Structures: Spores (7)7.5-10.5 x 4.5-6 μm , short-elliptical, smooth, in-

amyloid. Basidia 32-55 x 6.5-11 μm , narrowly clavate, 4-spored, the sterigmata slender, up to 6 μm long. Brachybasidioles rare, occurring sporadically and in groups, similar to basidioles but sphaeropedunculate, 10-14 μm broad at apex, intergrading with normal basidioles, rarely initiating sterigmata. Pleurocystidia and cheilocystidia absent. Gill trama of divergent hyphae 3-14 μm broad. Cuticle an ixocutis 40-175 μm deep, the hyphae 1.7-5.5 μm broad, gelatinous, light fuscous, more or less repent or occasionally erect, radial and loosely interwoven, underlain by a compact layer of brownish hyphae transitional to the context. Pileal trama of radial, slightly interwoven hyphae; hypodermium not seen. Stipe surface of narrow, light brown hyphae here and there reflexed and aggregated into squamules, the terminal elements cylindrical, occasionally very slightly gelatinized but not forming a discrete gelatinous veil. Clamp connections present in the cuticle, gill and pileal tramas, stipe surface, and stipe context.

Habit and Habitat: Scattered to gregarious on soil or among mosses (*Pleurozium*, *Sphagnum*) under spruce, hemlock, or other conifers.

Material Studied: ACAD 12232, River Head, Queens Co., 11 Oct, 1968; ACAD 12242, near Denver, Guysborough Co., 14 Oct. 1968; ACAD 12279, Gaspereau Valley, Kings Co., 29 Oct. 1968.

Remarks: *Hygrophorus tephroleucus* var. *tephroleucus* is a small mushroom distinguished by its viscid, brown to gray-brown pileus and its cinerescent to finely fuscous-squamulose stipe. In both these respects, it resembles *H. pustulatus* which is larger and has a more coarsely ornamented stipe. Spore size does not vary significantly between the two. For further comparison of these two species, see *H. pustulatus*.

Young sporophores may be mistaken for small specimens of *H. agathosmus*, in which the stipe is also white and cinerescent. However, *H. agathosmus* has a decidedly gray pileus and a pronounced amygdaline odor.

Bresadola (1928) and Lange (1940), while not definitely describing the stipe as dry, failed to mention any viscosity. The thin layer of gluten disappears very soon, depending on weather conditions, and thus, the stipe appears dry. Consequently, the species may be keyed in both Subsections *Hygrophorus* and *Camarophylli*.

Lange (1940) noted that *H. tephroleucus* is the smallest of the *Limacium* group (now Section *Hygrophorus*).

20. *Hygrophorus pustulatus* (Fr.) Fr.

Hymen. Eur., p. 411. 1874.

Agaricus pustulatus Fr., Syst. Myc. 1: 34. 1821.

Limacium pustulatum (Fr.) Kummer, Führ. in Pilzk., p. 119. 1871.

Figs 45, 46.

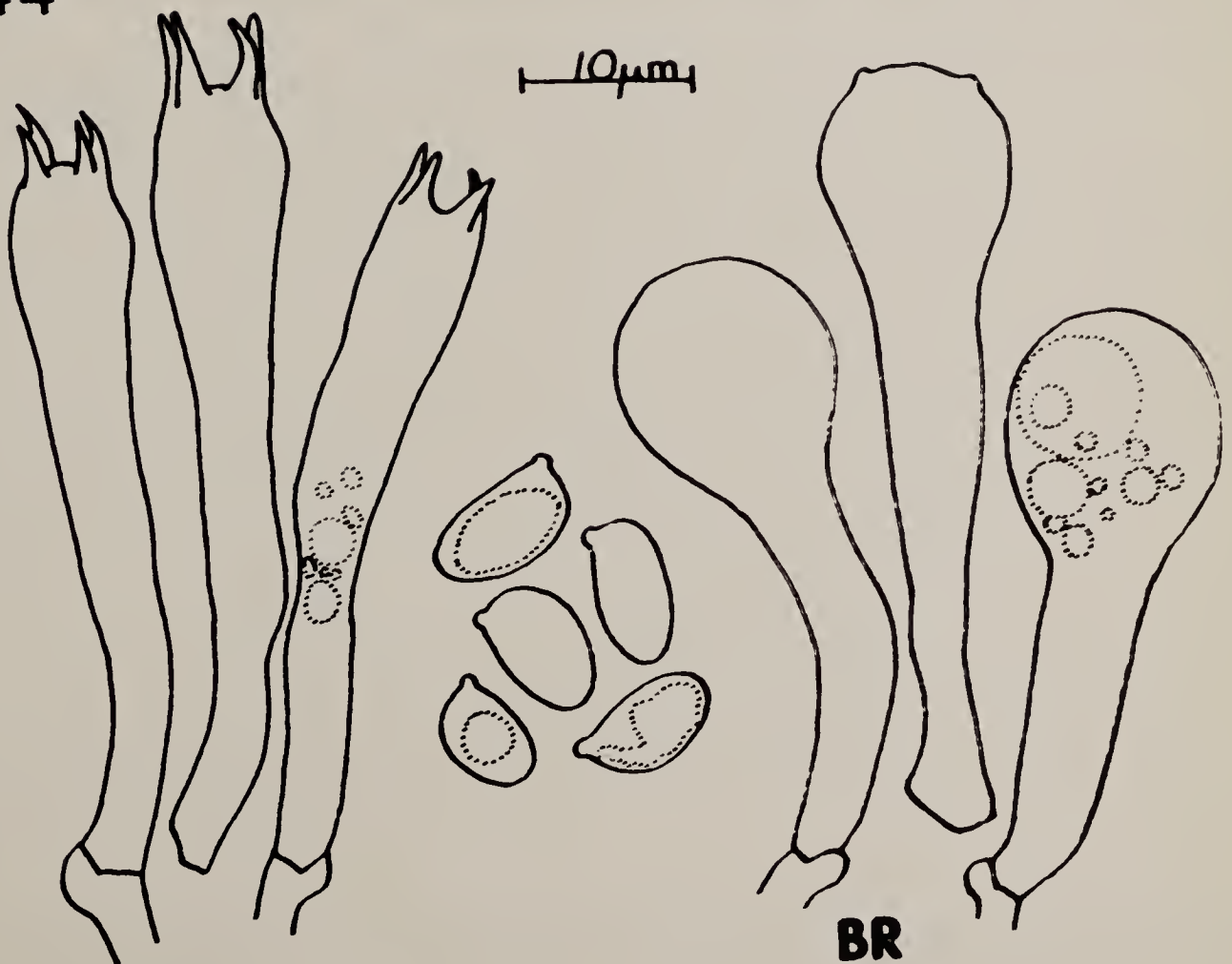
Basidiocarp: Pileus 3-5.5 cm broad, convex-depressed, becoming depressed with margin uplifted and wavy, glutinous to viscid when moist, drying dull or slightly polished, virgate, fuscous to medium brown on disc, paling to sallow (4D3) (ISCC 91) on margin, sometimes uniformly beige (4C3) (ISCC 90) to putty (4B2) (ISCC 84); context

Figs 43, 44. *H. tephroleucus* var. *tephroleucus*. Fig 43. ACAD 12242, X 1.0. Fig 44. ACAD 12232, spores and basidia; ACAD 12242, brachybasidioles (BR) from hymenium near stipe; redrawn by permission of the National Research Council of Canada from the *Canadian Journal of Botany*, 48, pp. 403-411. 1970.

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46



Figs 45, 46. *H. pustulatus*. Fig 45. DG-1573 (D.W. Grund), X 1.0. Fig 46. ACAD 12286, basidia, and spores.

rather thin, soft, whitish; odor and taste not distinctive. Lamellae short-decurrent, whitish, moderately narrow (to 5 mm) in mature pilei, subdistant, thick, occasionally intervenose. Stipe 4-5.5 cm long, 5-10 mm thick at apex, white, eventually brown-dotted over entire length, subviscid near base, dry above, minutely scabrous overall but more coarsely so above, the squamules coalescing just beneath the lamellae in a light brown, floccose ring (not a velar remnant), equal or slightly narrowed above, sometimes subcompressed or twisted, white within, stuffed.

Microscopic Structures: Spores (7)7.5-10.5(11.5) x 4.5-6(7) μm , short-elliptical, smooth, inamyloid. Basidia 40-60 x 6.5-9.5 μm , long-clavate, 4-spored, the sterigmata stout and prominent, up to 6.5 μm long. Pleurocystidia and cheilocystidia absent. Gill trama of divergent hyphae 4-20 μm broad. Cuticle a rather narrow ixotrichodermium, 43-78 μm deep, sometimes approaching an ixocutis, the hyphae 2.3-3.5 μm broad, subgelatinous, tangled, erect to repent, colorless to light fuscous or yellow-brown. Pileal trama radial and slightly interwoven; hypodermium not seen. Stipe surface of colorless to yellow-brown hyphae 2.5-7 μm broad, in places tangled and knotted to form the squamules, the terminal segments clavate to slightly bulbous, occasionally subgelatinous near the base; no distinct gelatinous veil seen. Clamp connections present in the cuticle, gill and pileal tramas, stipe surface, and stipe context.

Habit and Habitat: Scattered in spruce woods. Infrequent.

Material Studied: ACAD 12286, North Mountain, Kings Co., 29 Oct. 1968.

Remarks: The above description is based on a single collection of mature to old sporocarps. This is the first record of this species in Nova Scotia.

Hygrophorus pustulatus closely resembles *H. tephroleucus* var. *tephroleucus* but is larger and stouter, and has coarser stipe ornamentation. Occasionally, darkening of the squamules may be delayed, as in the specimens illustrated (Fig 45), and the scabrous stipe then appears essentially white.

Lange (1940) described the pileus of *H. pustulatus* as minutely squamulose on the disc, a feature not mentioned by Hesler and Smith (1963) and not encountered in the Nova Scotian specimens. However, he added that the pileal squamules may be washed away in wet weather, and then *H. pustulatus* approaches *H. tephroleucus*. Heim (1957) reported the pileus of *H. pustulatus* as woolly-fibrillose.

Bresadola (1928) appeared to have the 2 species confused. He attributed an appressed-scaly pileus to *H. tephroleucus* and a subglabrous one to *H. pustulatus*. Moreover, he described *H. pustulatus* as smaller than *H. tephroleucus*, with larger spores. His illustration of *H. pustulatus* f. *minor* more closely resembles our concept of *H. tephroleucus* than does his illustration of the latter species.

In *H. pustulatus*, as in many other species of Subsection *Hygrophorus*, the gelatinous stipe veil quickly disappears as the sporophores age. Hesler and Smith (1963) reported it as absent from the beginning on most of the upper stipe. Bresadola (1928), Heim (1957) and Lange (1940) omitted to mention viscosity of stipe. Thus, the species is keyed in both Subsections *Hygrophorus* and *Camarophylli*.

Subsection CAMAROPHYLLI Hes. & Sm.

N. Am. Spec. of *Hygrophorus*, p. 309. 1963.

Stipe dry, lacking a gelatinous veil; lamellar trama divergent.

Type species: *H. camarophyllus* (Fr.) Dumée.

Series PUDORINI (Bataille) Hes. & Sm.
N. Am. Spec. of *Hygrophorus*, p. 332. 1963.

Stipe apex ornamented with white squamules which stain yellow in KOH, and become yellow-brown to red-brown with age.

Type species: *H. pudorinus* (Fr.) Fr.

21. ***Hygrophorus pudorinus* (Fr.) Fr. var. *pudorinus* f. *pudorinus*.**

Epicr. Myc., p. 322. 1838.

Agaricus pudorinus Fr., Syst. Myc. 1: 33. 1821.

Limacium pudorinum (Fr.) Wünsche, Die Pilze, p. 117. 1877.

Figs 47, 48.

Basidiocarp: Pileus 1.5-4.5 cm broad, at first hemispheric or convex, expanding, at times broadly umbonate, margin persistently involute, slightly viscid, drying glabrous to faintly appressed-fibrillose, the disc sometimes obscurely tessellate-areolate, caramel (6C6) (ISCC 57) to pale tan on disc, paling to orange-white (5A2) (ISCC 73) on margin, at times uniformly salmon buff, brownish in age; context thick (2-8 mm on disc), white, tinged salmon under pellicle, spongy; odor and taste not distinctive. Lamellae broadly adnate, pale cream, flushed pale orange toward the pileus margin, fairly close to subdistant, occasionally forked near pileus margin, narrow (2-6 mm), edges even. Stipe 3.5-7.5 cm long, 8-15 mm thick at apex, white-squamulose above, the punctae quickly yellow in KOH and becoming yellow-brown to red-brown with age or drying, gradually pruinose to glabrose downwards, then with appressed fibrils and low uneven ridges below, streaked and laved with pale orange buff, pallid yellow at base, white and often salmon-tinged within, dry, stout, long-ventricose to subequal, occasionally subcompressed, solid to stuffed.

Microscopic Structures: Spores (7)8-10.5(11.5) x 4.5-6 μ m, short-elliptical, smooth, inamyloid. Basidia (36)50-70 x 6.5-10.5 μ m, long-clavate, 4-spored, the sterigmata up to 6 μ m long. Pleurocystidia and cheilocystidia absent. Gill trama of divergent hyphae 3-20 μ m broad. Cuticle an ixocutis 130-520 μ m deep, the hyphae gelatinous, more or less radial and repent, 2-4 μ m broad. Pileal trama radial and rather interwoven; hypodermium absent. Clamp connections present in the cuticle, gill trama, and pileal trama.

Habit and Habitat: Solitary, gregarious, or subcespitose on grassy soil or coniferous litter, under hemlock, fir, or other conifers. Frequent.

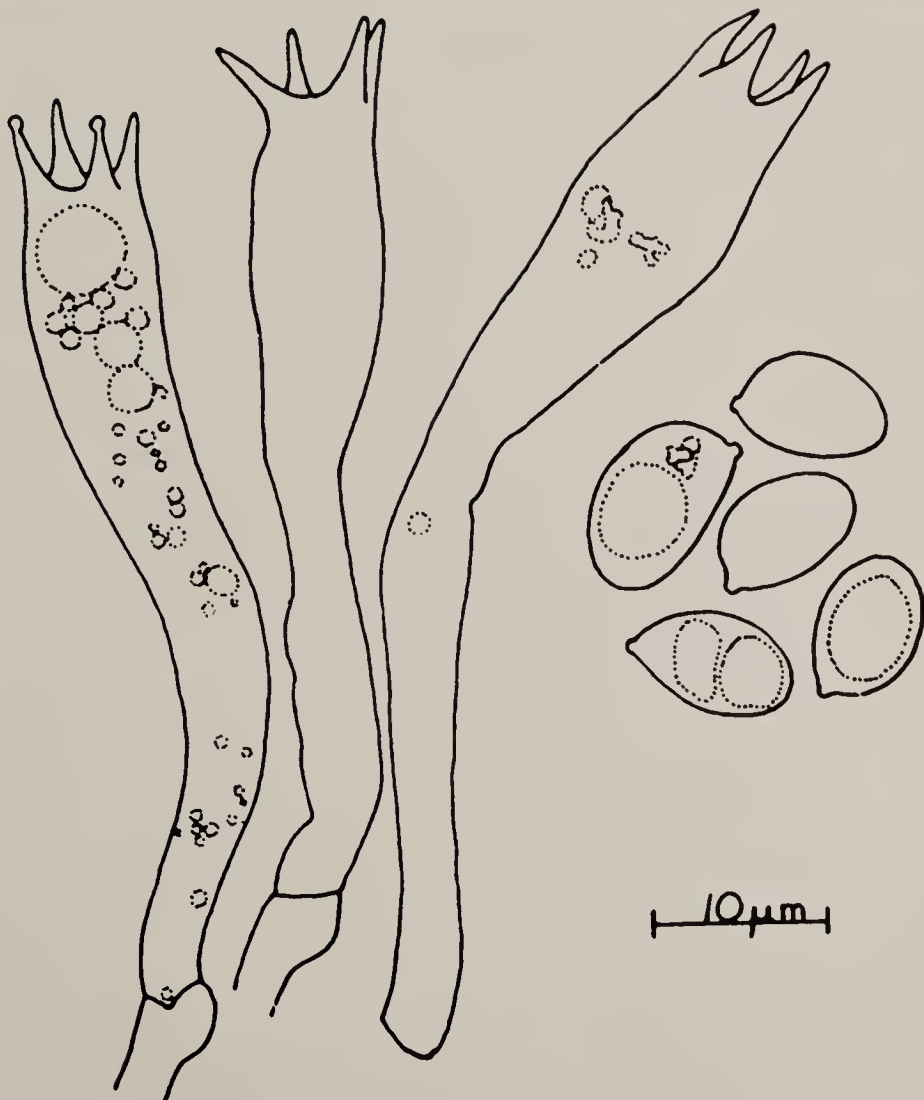
Material Studied: ACAD 5258, Cape Split, Kings Co., 16 Oct. 1955; ACAD 12115, Gaspereau Valley, Kings Co., 23 Oct. 1967; ACAD 12259, Willowdale, Pictou Co., 14 Oct. 1968; ACAD 12272, Willowdale, Pictou Co., 16 Oct. 1968.

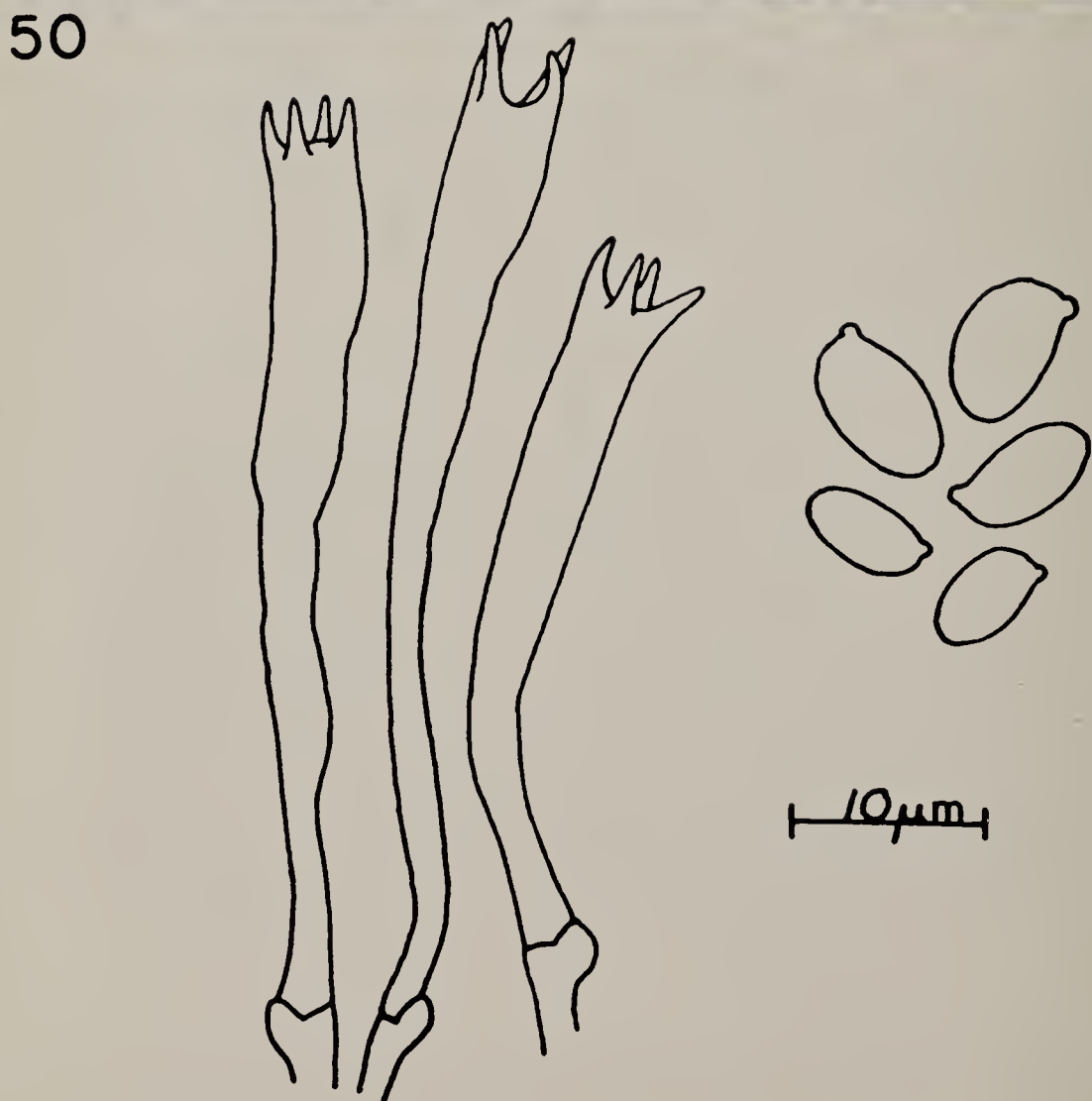
Remarks: This species is distinguished by the combination of a salmon to light buff pileus, and a stout dry stipe with apical squamules that become yellow- to red-brown on drying. The latter feature is missing from most of the earlier Nova Scotian collections of *H. pudorinus*, and we conclude that these specimens are probably *H. tennesseensis*. However, *H. pudorinus* has been collected previously in Nova Scotia, as *H. laurae* (See Doubtful and Excluded Species, p. 12). *H. laurae* is macroscopically similar to *H. pudorinus*, but the stipe is more slender, sheathed by a thin gelatinous

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veil, and lacking reddish punctae when dried. Moreover, its spores are smaller than those of *H. pudorinus*. *H. glutinosus* Pk. (not in Nova Scotia) also develops red-brown dots on the stipe apex, but the pileus is whitish instead of tan, drying bright yellow, and the stipe is rough and glutinous (Hesler & Smith 1963; Peck 1902).

Bresadola (1928) described the stipe of *H. pudorinus* as viscid, and the odor as subnauseous. Romagnesi (1962-63) also mentioned a viscid stipe and reported an odor of resin or jasmine.

Series RUBENTES (Fr.) Hes. & Sm.

N. Am. Spec. of *Hygrophorus*, p. 340. 1963.

Lamellae becoming vinaceous-spotted near edges, or vinaceous overall; lamellar trama divergent; stipe dry.

Type species: *H. erubescens* (Fr.) Fr.

22. *Hygrophorus purpurascens* (Fr.) Fr.

Epicr. Myc., p. 322. 1838.

Agaricus purpurascens Fr., Syst. Myc. 1: 34. 1821.

Limacium purpurascens (Fr.) Kummer, Führ. in Pilzk., p. 118. 1871.

Figs 49, 50.

Basidiocarp: Pileus 2 cm broad, convex with involute margin or disc at times depressed, slightly viscid, the pellicle separable and obscurely appressed-fibrillose, the inrolled margin cottony, the disc heavily streaked and flushed dark vinaceous brown (9F7) (ISCC 44), becoming pale, yellowish white (2A2) (ISCC 92) on the margin; context white, thick (4 mm on disc), spongy; odor and taste mild. Lamellae short-decurrent, whitish at first, soon ivory (4B3) (ISCC 90) and flushed drab pink near the edges, 3 mm broad, subdistant, rather thin, edges even. Stipe 5 cm long, 5 mm thick at apex, white above, streaked and laved below over most of length with vinaceous to brownish fibrils, white within, dry, pruinose-scurfy above, appressed-fibrillose below, equal, attenuated or subradicating at base, terete, solid. Partial veil whitish, sparse, cottony to cortiniform, leaving an evanescent, superior annulus. Vinaceous surface hyphae of pileus and stipe quickly yellowish to yellow-brown in KOH; pileal context very slightly yellowish, and stipe context unaffected by KOH.

Microscopic Structures: Spores 6-8 (10) x 3.5-5(6) μ m, ellipsoidal, smooth, inamyloid. Basidia 32-49 x 3.5-5 μ m, long-clavate to subcylindric, very slender, often flexuous, 4-spored, the sterigmata slender and up to 5 μ m long. Pleurocystidia and cheilocystidia absent. Gill trama divergent from a grayish, ill-defined mediostrate, the hyphae narrow, 3-8 μ m broad. Cuticle an ixocutis, 60-130 μ m deep, of radial, appressed, light vinaceous, gelatinized hyphae 2.3-4 μ m broad. Pileal trama interwoven, the hyphae more or less radially disposed; hypodermium absent. Clamp connections present on hyphae of the cuticle, gill trama, and pileal trama.

Habit and Habitat: Solitary in coniferous woods. Rare.

Material Studied: ACAD 12277, Centreville, Kings Co., 27 Oct. 1968.

Remarks: The above description is based on a single, unexpanded sporocarp, and data on mature specimens are lacking. Despite several previous collections of this

species (Bird & Grund 1970), *H. purpurascens* is uncommon in Nova Scotia, and subsequent finds should receive careful consideration.

Hygrophorus purpurascens is distinguished from other members of Series *Rubentes* by its partial veil. It most closely resembles *H. capreolarius*, which is more densely streaked vinaceous overall, and tends to become appressed-scaly on the disc.

Peck (1907) reported that North American specimens differ from the typical European form in having a fibrillose instead of squamulose partial veil, and whitish instead of purplish lamellae. Although our experience with fresh specimens of *H. purpurascens* is limited, ACAD 12277 corresponds well with Peck's observations.

23. *Hygrophorus capreolarius* (Kalchbr.) Sacc.

Fl. Ital. Crypt., Hymen., p. 342. 1915.

Figs 51, 52.

Basidiocarp: Pileus 1-3.5 cm broad, convex with incurved margins young, expanding, at times broadly umbonate at maturity, viscid, soon dry, in age minutely scaly-dotted on disc, obscurely virgate towards margin, photo brown (9F8) (ISCC 44) on disc, slightly paler at margin where the fibrils separate, decolorizing to yellow in KOH; context thick (2-6 mm on disc), pallid cream or tinged vinaceous, soft, spongy; odor and taste not distinctive. Lamellae adnate at first, soon decurrent, pallid at first, becoming pinkish buff with darker, sordid vinaceous spots, in age sordid pinkish buff to dull grayish vinaceous, rather narrow to moderately broad (1-5 mm), subdistant, occasionally intervenose, thickish, brittle, edges even. Stipe 3.5-7 cm long, 6.5-14 (23) mm thick at apex, pallid vinaceous above, heavily streaked below with appressed, dark vinaceous to oxblood fibrils, quickly yellow in KOH, dry, normally equal or long ventricose, at times tapering downwards and subradicating, at times subcompressed; context whitish, stained light vinaceous around worm-holes, solid.

Microscopic Structures: Spores 6-9.5(10.5) x 3.5-7 μ m, ellipsoidal, smooth, inamyloid. Basidia 30-55 x 4.5-9.5 μ m, long-clavate, slender, mostly 4-spored but frequently 2- and 3-spored in the same gill, the sterigmata stout to slender, up to 10.5 μ m long. Pleurocystidia and cheilocystidia absent. Gill trama of divergent hyphae 3.5-10.5 μ m broad. Cuticle a well-defined ixocutis 95-300 μ m deep, of interwoven, more or less repent, colorless to light vinaceous, gelatinous hyphae 3.5-15 μ m broad; hypodermium absent. Clamp connections present in the cuticle, the gill trama, and the pileal trama.

Habit and Habitat: Gregarious in coniferous woods. Moderately rare.

Material Studied: ACAD 12205, Beinn Bhreagh, near Baddeck, Victoria Co., 25 Sept. 1968; ACAD 12239, near Denver, Guysborough Co., 14 Oct. 1968.

Remarks: This species differs from *H. purpurascens* in its darker, more uniform, vinaceous brown colors and the absence of a fibrillose partial veil. Our specimens differ from descriptions in the available literature in that the lamellae are persistently pallid pinkish buff and not immediately concolorous with the pileus.

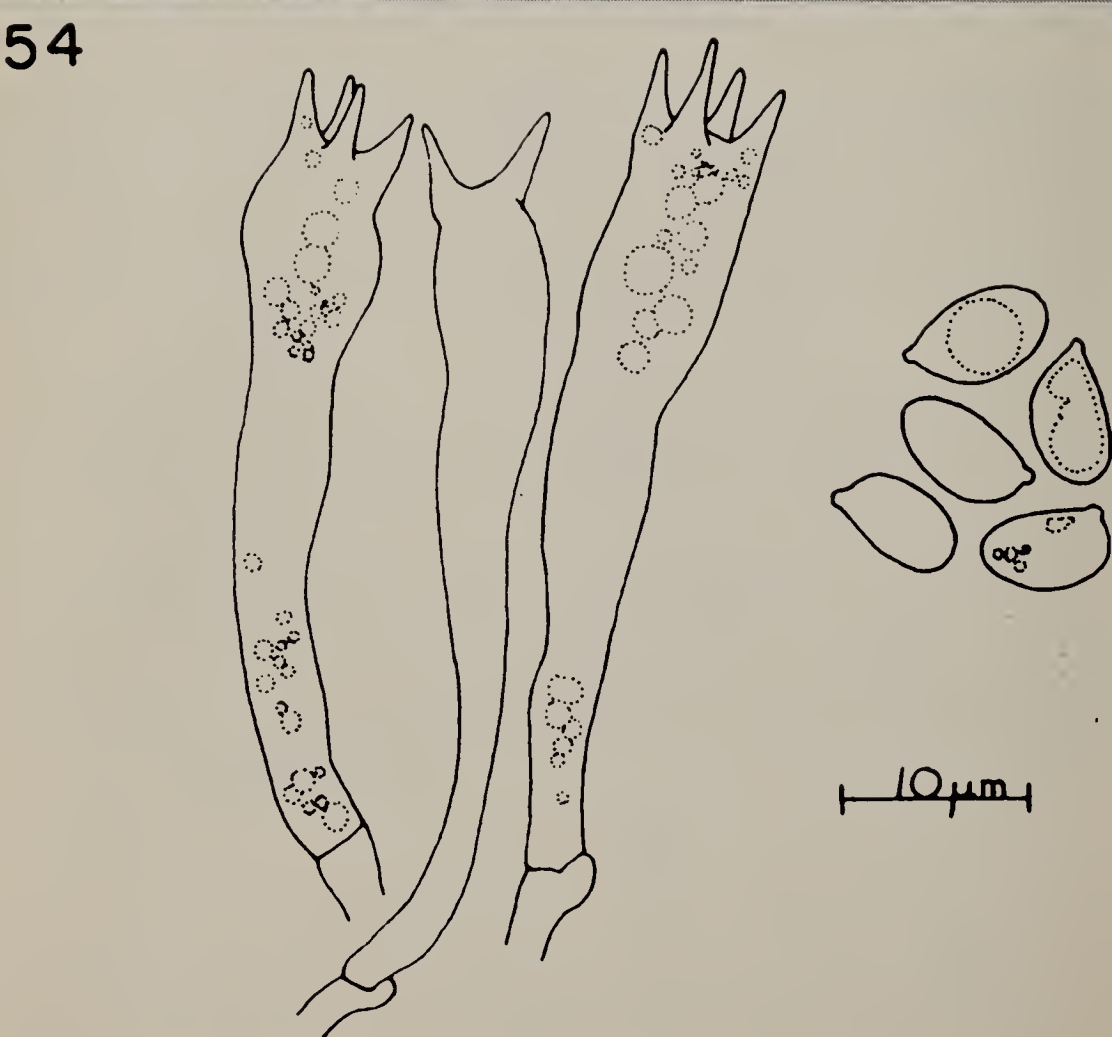
Imazeki and Hongo (1957) listed *H. purpureobadius* Imai as a synonym.

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24. *Hygrophorus erubescens* (Fr.) Fr. var. *erubescens*

Epicr. Myc., p. 322. 1838.

Agaricus erubescens Fr., Syst. Myc. 1: 32. 1821.*Limacium erubescens* (Fr.) Wünsche, Die Pilze, p. 117. 1877.

Figs 53, 54.

Basidiocarp: Pileus 3-9 cm broad, at first convex with involute margin, expanding to planoconvex, at times subumbonate, finally plane with uplifted margin, viscid when moist, soon dry, glabrous to appressed fibrillose and virgate beneath the gluten, occasionally appressed scaly on the disc, disc heavily streaked photo brown (9F8) (ISCC 44), oxblood red (9E7) (ISCC 43), or dark vinaceous, gradually pallid yellowish tan, or pale yellowish white (2A2) (ISCC 92), or milk white (1A2) (ISCC 104) towards the margin, at times uniformly pinkish brown when young, sometimes staining yellowish when rubbed, the vinaceous hyphae quickly decolorizing to yellow in KOH; context thick (2-11 mm on disc), whitish to cream, soft, spongy; odor and taste mild, not distinctive. Lamellae adnate young, soon decurrent, cream (4A3) (ISCC 89) to pale yellowish white (2A2) (ISCC 92), becoming spotted sordid vinaceous near the edges and where insect-damaged, occasionally flushed dull pinkish, narrow to moderately broad (2.5-12 mm), close to subdistant, sometimes obscurely intervenose, rather thin, edges even. Stipe 3-7.5 cm long, 6-26 mm thick at apex, whitish or pale yellowish, sparsely streaked or flushed dark vinaceous brown or pallid brownish over lower portion, sometimes staining yellowish when rubbed, the vinaceous fibrils rapidly yellow in KOH, dry, the colored fibrils sometimes terminating above in a fibrillose annular zone but true veil absent, pruinose to minutely scabrous above, becoming appressed-fibrillose below, equal, or narrowed or expanded towards base; context whitish, rarely streaked pale vinaceous, usually staining dull yellow at the base, solid.

Microscopic Structures: Spores 6-9 x 4-6 μm , ellipsoidal, smooth, inamyloid. Basidia 28-49 x 5.5-9(11) μm , slender, clavate, mostly 4-spored, rarely also 2-spored, the sterigmata slender, up to 6.5 μm long. Pleurocystidia and cheilocystidia absent. Gill trama divergent. Cuticle an ixotrichodermium 50-215 μm thick, of slightly gelatinized, more or less erect, tangled hyphae 2.3-6 μm broad, tending to become repent and form an ixocutis when dried. Pileal trama of radial, interwoven hyphae 5-20 (27) μm broad; hypodermium not seen. Clamp connections present in the gill trama, cuticle, and pileal trama.

Habit and Habitat: Solitary, scattered, or gregarious on soil in old field spruce, or under hemlock in mixed woods. Frequent.

Material Studied: ACAD 12116, Gaspereau Valley, Kings Co., 23 Oct. 1967; ACAD 12119, 12121, Gaspereau Valley, 3 Nov. 1967; ACAD 12241, near Denver, Guysborough Co., 14 Oct. 1968.

Remarks: This rather variable species is easily confused with its close relative, *H. russula*. In general, mushrooms in this series which have a whitish or light yellowish pileus, heavily streaked and dotted vinaceous brown on the disc, are *H. erubescens*.

var. *erubescens*. Those having a pinkish or yellowish pileus with little dark vinaceous color are *H. russula*. In addition, *H. erubescens* as treated here has slightly larger spores than *H. russula*. It also is found primarily in coniferous woods, whereas *H. russula* is associated with deciduous trees. Closeness of lamellae, usually attributed to *H. russula*, is a variable feature and can also occur in *H. erubescens* (see *H. russula* for further comment).

The specimens illustrated by Bresadola (1928) and Imazeki and Hongo (1957) are suffused with a rosy tinge. This feature did not occur in any of our specimens, although Hesler and Smith (1963) mentioned "a pink tinge often pervading the entire pileus" with regard to North American material. Moreover, the lamellae were typically whitish with dull vinaceous spots (cf. Bresadola, 1928), and lacked a general pinkish flush (Hesler & Smith 1963). Basidia are considerably shorter in the Nova Scotian specimens than reported previously for this species (Bresadola 1928; Hesler & Smith 1963), while the cuticle tends to be an ixotrichodermium rather than an ixocutis. Finally, we have not observed a layer of parallel periclinal hyphae at the base of the pileal trama (Bird & Grund 1970), said to be a distinguishing feature of var. *erubescens* (Hesler & Smith 1963).

25. *Hygrophorus russula* (Fr.) Quél.

Ench. Fung., p. 49. 1886.

Agaricus russula Fr., Hymen. Eur., p. 52. 1874.

Tricholoma russula (Fr.) Gill., Champ. Fr., p. 91. 1874.

Melanoleuca russula (Gill.) Murr., N. Am. Flora 10: 22. 1914.

Figs 55, 56.

Basidiocarp: Pileus (1)3.5-7 cm broad, at first convex with strongly involute margin, expanding to broadly convex and umbonate, finally depressed, viscid, soon dry and dull to polished, glabrous to faintly appressed fibrillose, at times rimose-areolate on disc, obscurely virgate towards periphery, margin cottony young, pale yellowish-tan with whitish margin at first, slowly becoming unevenly streaked and flushed shell pink (8A3) (ISCC 28) over cream (4A3) (ISCC 89) ground, finally pink over all; context thick (7-21 mm on disc), fleshy, whitish or flushed pale pink toward margin; odor and taste not distinctive. Lamellae adnate-subdecurrent, dingy white to pale yellowish, soon spotted pink to sordid vinaceous near edges, often flushed pinkish, thin, rather close, narrow (3-5 mm), occasionally intervenose near the stipe, edges even. Stipe (3)5.5-8 cm long, (8)15-19 mm thick at apex, whitish above, yellowish downwards, darkening with handling, rarely tinged pinkish, lacking vinaceous streaks, whitish within, dry, fibrillose-pruinose at apex, coarsely and irregularly fibrillose-striate or appressed fibrillose below, not annulate, stout, long-ventricose young, soon equal or the base tapered and embedded, solid.

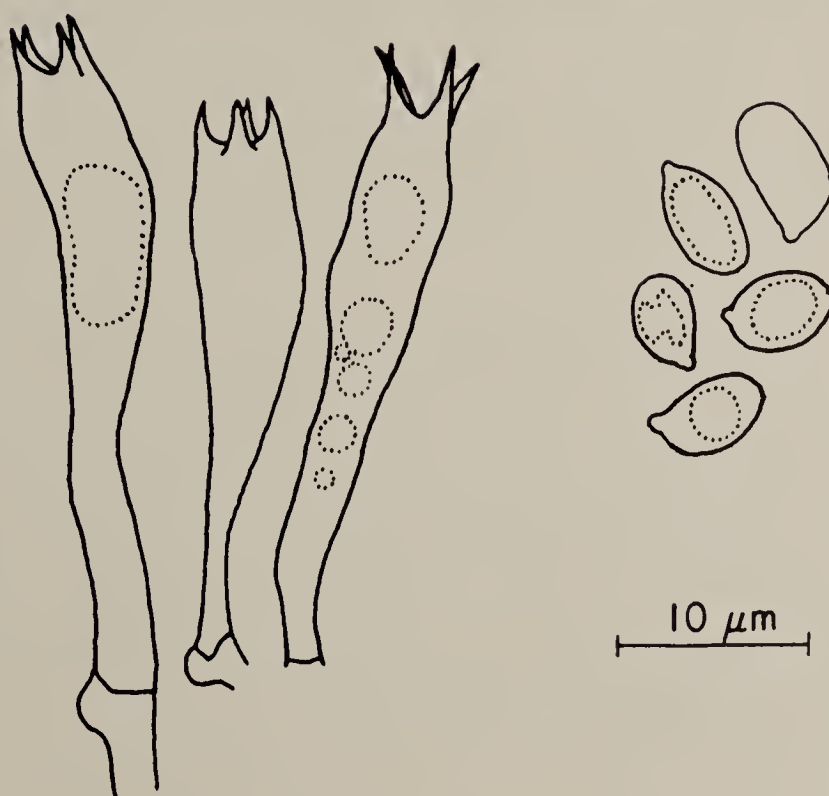
Microscopic Structures: Spores (4.5)5-7 x 3-4 μm , short-elliptical, smooth, inamyloid. Basidia 28-46 x 4.5-7(8) μm , clavate or subcylindrical, slender, 4-spored, the sterigmata slender, up to 6.5 μm long. Pleurocystidia and cheilocystidia absent. Gill trama of divergent hyphae 3-12.5 μm broad, distinct from the pileal context hyphae by their more yellow color in fresh section. Cuticle a narrow zone (to 25 μm deep) of roughly radial, interwoven, appressed to erect, slightly gelatinized hyphae 1.7-4.5 μm broad, gradually merging with the context and easily absorbed into it. Pileal trama of radial, interwoven hyphae, often more regular near the cuticle, colorless, sharply demarcated from the yellow subhymenial hyphae; hypodermium absent. Clamp connections present in the cuticle, gill trama, and pileal trama.

Habit and Habitat: Solitary to gregarious on soil under hardwoods in birch-hemlock woods. Infrequent.

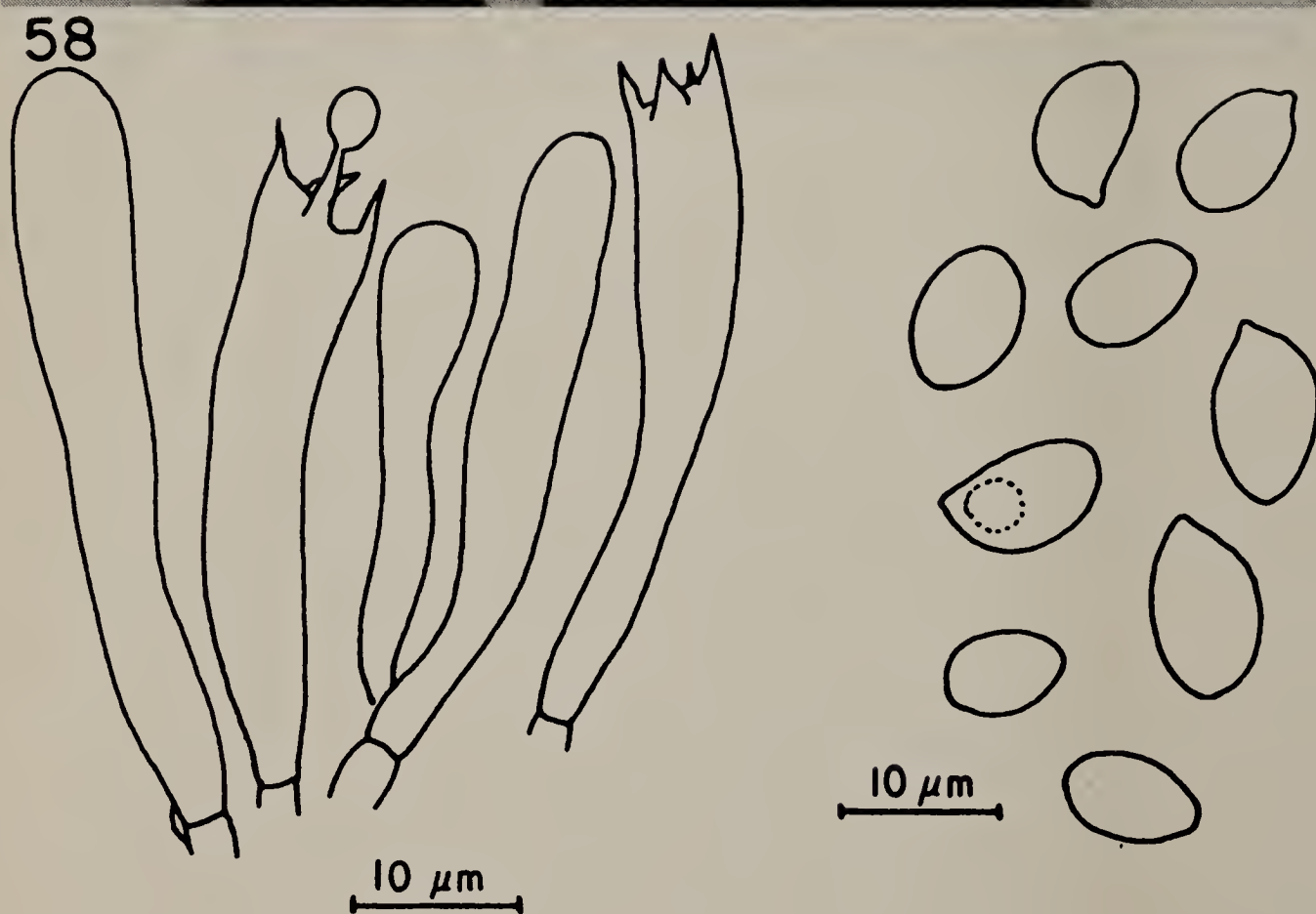
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Figs 55, 56. *H. russula*. Fig 55. Courtesy of K.A. Harrison, X .75. Fig 56. ACAD 12217, basidia and spores.



Figs 57, 58. *H. tennesseensis*. Fig 57. H.-12384 (K.A. Harrison), X .8. Fig 58. ACAD 10551, basidia, basidioles, and spores.

Material Studied: ACAD 12217: Gaspereau Valley, Kings Co., 5 Oct. 1968; ACAD 12281, Gaspereau Valley, Kings Co., 29 Oct. 1968.

Remarks: So far, Nova Scotian material has displayed none of the various vinaceous hues attributed to this species in the available literature. The shell pink tints developed very slowly, sometimes not appearing until after maturity.

Hygrophorus erubescens var. *erubescens* is a very closely related species and is difficult to distinguish from local specimens of *H. russula*. A popular macroscopic feature used to separate the two is the closeness of gills, with the gills being close to crowded in *H. russula*, and subdistant to close in *H. erubescens*. Hesler and Smith (1963) expressed this quantitatively in terms of the number of gills reaching the stipe. We find that this number depends on the diameter of the stipe and that Hesler and Smith's figures cannot be applied to our collections. Spore size is a more reliable feature, with *H. russula* having slightly smaller spores than *H. erubescens*.

It should be remembered that *H. russula* is macroscopically variable, but that the pileus tends to be pinkish over all instead of yellowish white with a dark vinaceous disc as in *H. erubescens*. *H. purpurascens* is darker vinaceous and has a conspicuous fibrillose partial veil in unexpanded sporocarps.

Series FULVENTES (Fr.) Hes. & Sm.

N. Amer. Spec. of *Hygrophorus*, p. 353. 1963.

Pileus rusty brown, tan, pale yellow-orange, or vinaceous; lamellar trama divergent; stipe dry, lacking brownish squamules.

Type species: *H. arbustivus* Fr.

26. *Hygrophorus tennesseensis* Sm. & Hes.

Lloydia 2: 40. 1939.

Figs 57, 58.

Basidiocarp: Pileus 4-10 cm broad, convex with inrolled margins when young, becoming plane to centrally depressed with rounded margins, glabrous, viscid, often with a layer of gluten, light brown (6D8) (ISCC 54) at center, shading to Pompeian yellow (5C6) (ISCC 72) at margin; context firm, pallid, thick; odor of raw potatoes and jasmine; taste bitter. Lamellae adnate to subdecurrent, white; lamellulae interspersed at margin. Stipe 4-8 cm long, 6-15 mm thick, tapering at base, white, glabrous to minutely fibrillose, apex minutely scabrous, moist, not viscid; context white, solid.

Microscopic Structures: Spores 8-10 x 4-5(5.5) μm , ellipsoid, smooth, inamyloid. Basidia 35-45(50) x 5-7 μm , clavate to subcylindric, mostly 4-spored, sometimes 2-spored, hyaline to slightly brownish in KOH. Pleurocystidia and cheilocystidia absent. Lamellar trama with a divergent mediostratum and narrow interwoven subhymenium. Pileal surface a thin pellicle 70-100 μm thick, of gelatinizing, loosely interwoven hyphae. Clamp connections present in the lamellar trama.

Habit and Habitat: Gregarious under conifers in mixed woods during early autumn.

Material Studied: ACAD 1764, Kentville, Kings Co., 24 Sept. 1952; ACAD 2637: Kentville, Kings Co., 24 Sept. 1953; ACAD 10551, 2.4 km from West Gaspereau, Kings Co., 23 Sept. 1973.

Remarks: *Hygrophorus tennesseensis* is a beautiful mushroom, with its brown, multishaded pileus and white lamellae and stipe. The odor of raw potatoes or jasmine is distinctive, along with the bitter taste. This species is, however, easily con-

fused with *H. pudorinus*, and most early collections of *H. tennesseensis* in Nova Scotia were in fact assigned to that species.

27. *Hygrophorus pacificus* Sm. & Hes.

Lloydia 2: 42. 1939.

Fig 59.

"Pileus 3-8 cm broad, convex, margin long remaining incurved, becoming plane and variously lobed, notched or wavy in age, colors evenly 'russet' to 'tawny' when young, at maturity 'tawny' on the disc and 'pinkish buff' on the margin, viscid, glabrous, margin faintly tomentose under a lens, usually plicate crenate when unexpanded. Context whitish, rather thin and rigid; odor strong, penetrating and aromatic, taste mild.

Lamellae bluntly adnate or decurrent by a tooth, edges even, 'marguerite yellow' to 'cream-buff' when young, 'cream color' in age, distant, broad (1 cm), often forking near the margin of the pileus, thickish.

Stipe 4-7 cm long, 8-15 mm thick, concolorous with the lamellae or whitish, equal above a narrowed base, solid or sometimes hollowed at the apex, dry, evenly fibrillose-pruinose over upper half with whitish fibrils, glabrous and unpolished below.

Spores 10-14 x 5.5-7.5 μ , ellipsoid, smooth, pale yellowish in Melzer's reagent. Basidia 50-82 x 7-9 μ , 2- and 4-spored, sterigmata stout. Pleurocystidia and cheilocystidia absent. Gill trama divergent, hyphae 3-8 μ broad. Cuticle an ixotrichodermium, hyphae more or less erect and tangled, 2.5-5 μ broad, at times finally repent and then resembling an ixocutis. No hypodermium differentiated. Pileus trama of radial hyphae. Clamp connections on the hyphae of the cuticle and gill trama. Lactifers present in the gill trama." (Hesler & Smith 1963).

Habit and Habitat: "Densely gregarious under spruce, . . ." (Hesler & Smith 1963). Rare.

Remarks: This primarily western species is not among the collections in the E.C. Smith herbarium at Acadia University. Hesler and Smith (1963) cited a collection made by K.A. Harrison in Kings County, N.S., on 21 Sept. 1955.

H. pacificus is similar in many respects to *H. odoratus*, but the pileus of the latter species is gray, becoming yellow-tinged. *H. agathosmus* has a dry stipe and an odor, but is gray and has smaller spores. Stout, tawny to pinkish buff sporophores may resemble *H. monticola*, which differs in its decurrent gills and its definitely amygdaline odor.

28. *Hygrophorus monticola* Hes. & Sm.

N. Am. Spec. of *Hygrophorus*, p. 359. 1963.

Figs 60, 61.

Basidiocarp: Pileus 2.5-7.5 cm broad, hemispheric young, expanding to convex, at times subumbonate, margin persistently incurved, subviscid when fresh, soon dry, glabrous, salmon-colored, flesh (6B3) (ISCC 57), or vinaceous on disc, paling to apricot yellow (5B6) (ISCC 76) or rarely pale yellowish white (2A2) (ISCC 92) on margin, at times with a drab beige bloom; context thick (3-16 mm on disc) whitish, compact, spongy; odor of bitter almonds; taste similar but less pronounced. Lamellae adnate to decurrent, pale yellowish white (2A2) (ISCC 92), cream, or champagne (4B4) (ISCC 90) subdistant, thick, narrow to moderately broad (2.5-12 mm) at times intervenose, edges even. Stipe 5.5-9.5 cm long, 7-22 mm thick at apex, pallid yellowish above, usually streaked light yellow-brown, apricot yellow (5B6) (ISCC 76),

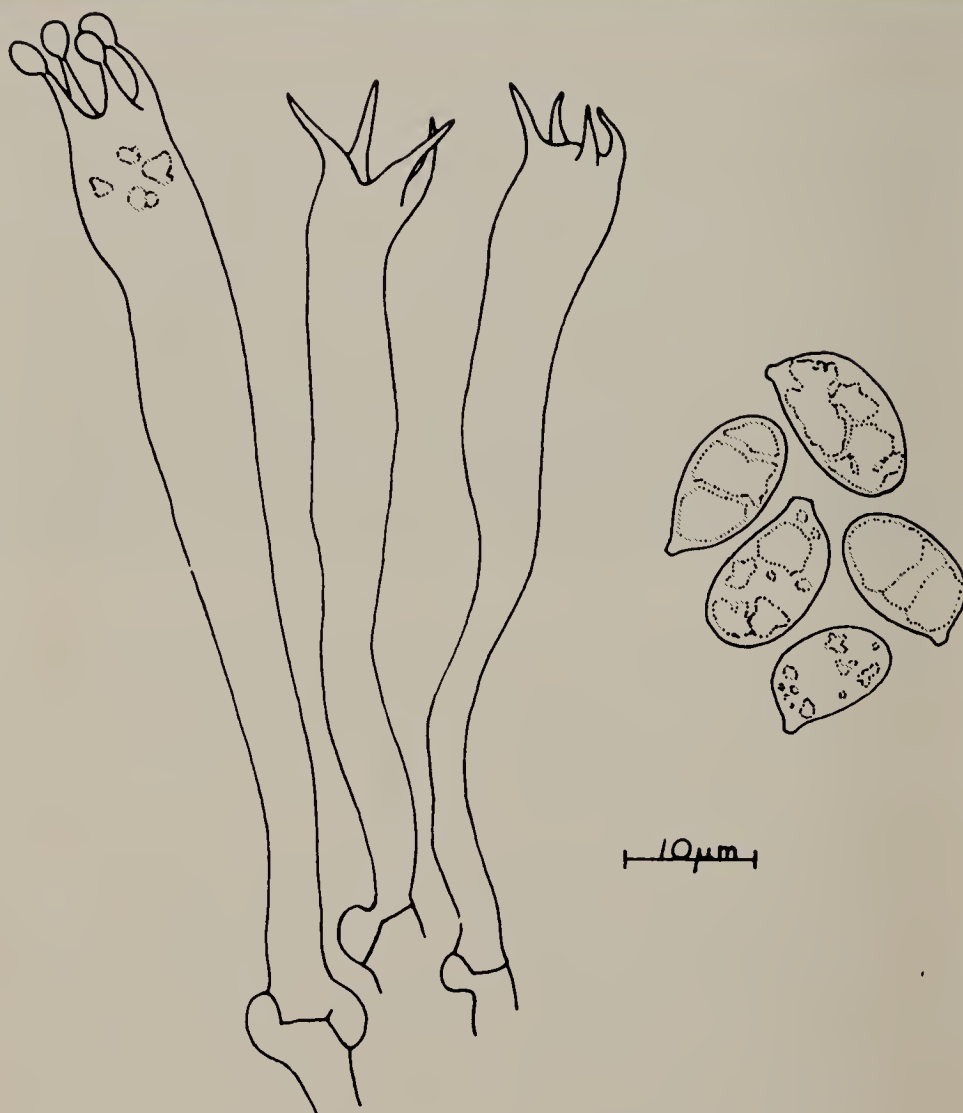
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Fig 59. *H. pacificus*. Smith 8732, X .8; from *North American Species of Hygrophorus*, by L.R. Hesler and A.H. Smith, (c) 1963 by the University of Tennessee Press, Knoxville; reprinted by permission of the University of Tennessee Press.



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Figs 60, 61. *H. monticola*. Fig 60. ACAD 12240, X .75. Fig 61. ACAD 12109, basidia and spores.

or tan below, pallid yellowish within, glabrous to pruinose at apex, smooth or fibrillose-ridged below, dry, equal, long-ventricose, or tapering to base, at times sub-compressed, solid.

Macroscopic Structures: Spores (9.5) 10.5-15.5(17.5) x 6-8.5(9.5) μm , elliptical, at times slightly obovate, inamyloid, smooth. Basidia 50-103 x 8-14.5 μm , narrowly clavate, 4-spored, the sterigmata large and prominent, to 9 μm long. Pleurocystidia and cheilocystidia absent. Gill trama of divergent hyphae 3-19 μm broad. Cuticle a thin ixocutis 27-54 μm deep, sometimes apparently absent in older pilei, the hyphae roughly radial and repent, subgelatinized, 3-6.5 μm broad. Pileal trama interwoven; hypodermium absent. Clamp connections large and prominent, present on the hyphae of the cuticle, gill trama and pileal trama, frequently double at the bases of the basidia.

Habit and Habitat: Gregarious to subcespitose in coniferous woods, especially under spruce. Frequent.

Material Studied: ACAD 12109, Wolfville, Kings Co., 6 Oct. 1967; ACAD 12122, Wolfville, Kings Co., 13 Oct. 1967; ACAD 12240, 12244, Aspen, Guysborough Co., 14 Oct. 1968.

Remarks: This robust, buff-colored fungus with its amygdaline odor and decurrent lamellae is unlikely to be confused with any other *Hygrophorus*. *H. pacificus* is similar but has a rusty brown pileus disc, an aromatic odor, and adnate lamellae. *H. agathosmus* has the same odor of almonds, but the pileal cuticle is gray and more gelatinized.

Hygrophorus monticola is one of the few eastern North American agarics that are typically larger than their western counterparts. Collection ACAD 12244 was a pallid, slender form growing among numerous typical specimens. Apart from the rather abnormal color and stature, the only difference was a slight tendency for the spores to be obovate, which we did not consider to be sufficient grounds for establishing a new variety.

Series CAMAROPHYLLI

Pileus gray, gray-brown or blackish brown; lamellar trama divergent; stipe dry.

29. *Hygrophorus inocybiformis* Sm.

Mycologia 36: 246. 1944.

Figs 62, 63.

Basidiocarp: Pileus 1-4 cm broad, conic young with incurved margin, becoming convex with a small, pointed umbo, broadly campanulate, or planoconvex, dry, appressed fibrillose, often appressed scaly or obscurely scabrous with age, earth colored (5F2) (ISCC 62) on disc, paling to hair brown (5E4) (ISCC 80) or bronze (5E3) (ISCC 80) on margin, darkening in KOH; context 1.5-7 mm thick on disc, membranous on margin, white, at times tinged cinereous; odor and taste mild, not distinctive. Lamellae short-decurrent, white at first, becoming cream (4A3) (ISCC 89) to ivory (4B3) (ISCC 90) with age, moderately narrow (2-5 mm deep), thickish, subdistant to distant, at times intervenose, edges even. Stipe 3.5-6.5 cm long, 5-15 mm thick at apex, white and silky to pruinose above the broken veil, streaked below with appressed clay (5D5) (ISCC 76) to soot brown (5F5) (ISCC 78) or light fuscous velar remnants, dry, annulus a superior, evanescent zone of whitish fibrils, not a moist, well-defined ring; context white, silky-shining, solid or loosely fibrous toward center.

Microscopic Structures: Spores 9.5-17 x 6-9 μm , elliptical to oblong-elliptical with apiculus blunt and sometimes apparently almost lateral, smooth, inamyloid. Basidia

44-94 x 8.5-14 μm , narrowly clavate, at times pedicellate, often very long, usually 4-spored but also occasionally 2- and 3-spored in some sporocarps, sterigmata large and prominent, up to 10 μm long. Pleurocystidia and cheilocystidia absent. Gill trama of divergent hyphae 4-17.5 μm broad. Cuticle an epicutis 90-220 μm deep, the hyphae radial, repent or reflexed in tufts, light smoky brown to yellow-brown, 7-15 μm broad, little differentiated in size from the context hyphae, the terminal elements cylindrical. Pileal trama of radial, rather interwoven hyphae 6.5-17.5 μm broad; hypodermium absent. Stipe surface of pale brown to yellow-brown, non-gelatinized hyphae, slightly narrower than the internal hyphae. Clamp connections present on the hyphae of the cuticle, gill trama, and pileal trama.

Habit and Habitat: Solitary, gregarious, or subcespitate on ground in hemlock and other coniferous woods; at times in moss. Infrequent.

Material Studied: ACAD 12122, Gaspereau Valley, Kings Co., 3 Nov. 1967; ACAD 12243, Newtown, Guysborough Co., 14 Oct. 1968.

Remarks: This species is much like *H. olivaceoalbus* var. *olivaceoalbus* but lacks the gelatinous cuticle and stipe veil. The broad, well-defined, brown surface hyphae revealed in sections of the stipe and pileus are quite unlike the surface hyphae of *H. olivaceoalbus* stipes and pilei, which are narrow, less distinct, and show at least a vestige of gelatinization. However, the zone of fuscous fibrils underlying the gelatinous layers in *H. olivaceoalbus* indicates a relationship with *H. inocybiformis*. If unexpanded specimens are available, the dry, fibrillose nature of the partial veil will readily distinguish this species from *H. olivaceoalbus*.

Hygrophorus inocybiformis is typically a western species in North America, with collections primarily from California and Idaho (Hesler & Smith 1963). The eastern counterpart corresponds quite closely except in two respects: (1) the lamellae are persistently white or whitish, developing an ivory to gray tint only in age; (2) the occasional presence of 2- and 3-spored basidia extends the upper limit of the spore size range.

30. *Hygrophorus camarophyllus* (Fr.) Dumée, Grandjean, & Maire

Bull. Soc. Mycol. Fr. 28: 292. 1912.

Agaricus camarophyllus Fr., Syst. Myc. 1: 99. 1821.

Hygrophorus caprinus Fr., Epicr. Myc., p. 326. 1836.

Camarophyllus caprinus (Fr.) Karsten, Hattsvamp., p. 224. 1879.

Hygrophorus burnhami Pk., N.Y. State Mus. Bull. 116: 56. 1907.

Camarophyllus burnhami (Pk.) Murr., N. Am. Flora 9: 389. 1916.

Limacium coprinus [sic.?] (Fr.) Singer, Ann. Myc. 34: 327. 1936.

Figs 64, 65

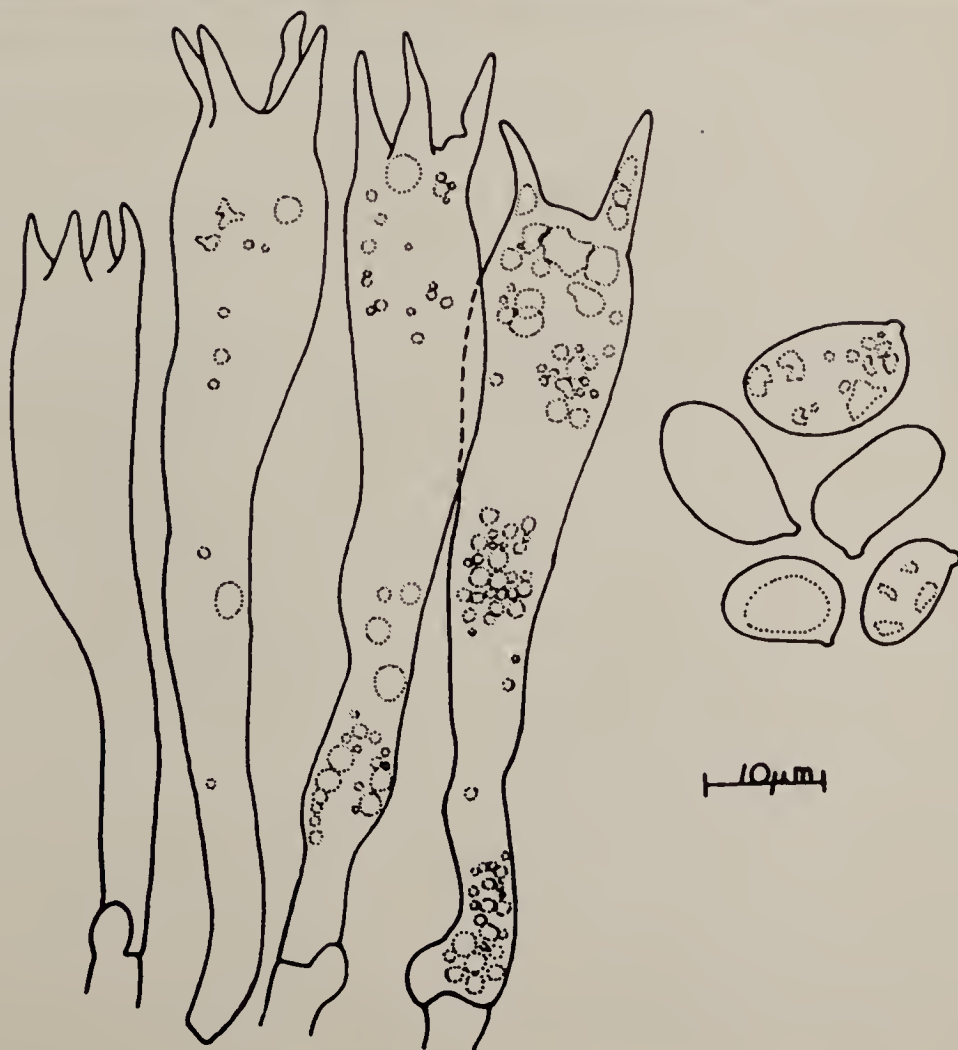
Basidiocarp: Pileus 4-9 cm broad, convex becoming broadly subumbonate-convex to nearly plane, slightly pruinose becoming glabrous, subviscid when wet, color smoky drab; context pallid, thin; odor slightly asphaltic or lacking, taste not distinctive. Lamellae adnate to subdecurrent, usually close, pallid to slightly grayish. Stipe 3-9 cm long, 0.8-2 cm thick, mostly equal, silky-fibrillose becoming glabrous at base, dry, concolorous with pileus commencing at point of lamellar attachment; context grayish, firm, solid.

Figs 62, 63. *H. inocybiformis*. Fig 62. ACAD 12243, X 1.0. Fig 63. ACAD 12122, basidia and spores; redrawn by permission of the National Research Council of Canada from the *Canadian Journal of Botany*, 48, pp. 403-411. 1970.

62

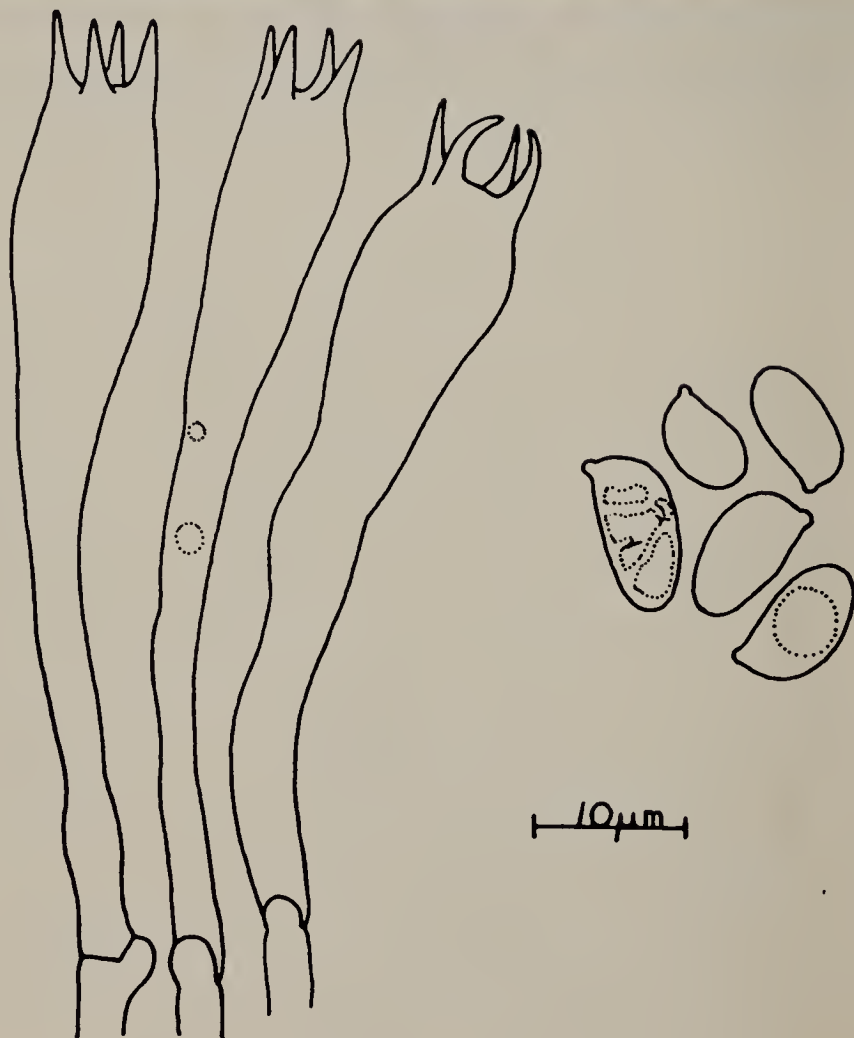


63





65



Figs 64, 65. *H. camarophyllus*. Fig 64. Smith 74012, X .75. Fig 65. ACAD 5254, basidia and spores.

Microscopic Structures: Spores 7-11 x 4-6 (6.5) μm , elliptical to oblong-elliptical, often broader at apicular end, smooth, inamyloid. Basidia (35) 43-71(95) x 6.5-10 μm , narrowly clavate, elongate, 4-spored, the sterigmata stout, up to 8 μm long. Pleurocystidia and cheilocystidia absent. Gill trama of divergent hyphae 3.5-15 μm broad. Cuticle an epicutis 100-260 μm deep, the hyphae light brown, radially appressed, slightly interwoven, nongelatinous, moderately broad (3-10.5 μm), gradually merging with the slightly broader context hyphae. Pileal trama radial and subparallel, somewhat interwoven over the hymenium, the hyphae 4.5-22 μm broad; hypodermium absent. Clamp connections present in the cuticle, the gill trama, and the pileal trama.

Habit and Habitat: "Gregarious under pine and spruce" (Hesler & Smith 1963).

Material Studied: ACAD 3939, ravine, Agriculture Experimental Station, Kentville, Kings Co., 13 Oct. 1958; ACAD 5255, Glenmont, Kings Co., 25 Oct. 1955; ACAD 5254, Plaster Mines, Victoria Co., 18 Sept. 1965.

Remarks: *Hygrophorus camarophyllus* is distinguished by its dry, fuscous pileus, its light fuscous to concolorous stipe, and its cinerescent lamellae. *H. inocybiformis* is similar in color of pileus and lamellae, but the stipe has ragged brown zones and streaks derived from a veil, and the spores are much larger (9.5-17 μm long). Old specimens of *H. agathosmus* with grayish to beige stipes differ in their viscid gray or gray-brown pilei and in their amygdaline odor.

The spores and basidia of the material examined are consistently oversized for this species. Ricken (1915) and Rea (1922) reported 9 μm as the upper limit of spore length. Murrill (1916) and Bresadola (1928) described the spores as ranging to 10 μm , and Peck (1907) gave a similar measurement of .004 inch for *H. burnhami*. In the collections cited above, spore length varies from (6.5)7-9.5 μm in ACAD 5255 to (7.5)8-11.5 μm in ACAD 5254.

31 *Hygrophorus agathosmus* Fr.

Epicr. Myc., p. 325. 1838.

Agaricus agathosmus Fr., Obs. Myc. 1: 16. 1815.

Agaricus cerasinus Berk., in Smith Engl. P1. 5²: 12. 1836.

Hygrophorus cerasinus (Berk.) Fr., Hymen. Eur., p. 410. 1874.

Figs 66, 67, 68.

Basidiocarp: Pileus 1-4 cm broad, hemispheric to convex young, becoming plano-convex and often subumbonate, margin inrolled and floccose-cottony at first, persistently decurved, sometimes uplifted, glutinous to viscid, the gluten at times granular on the disc, glabrous or very obscurely virgate beneath the gluten, pellicle separable, dull gray at first, yellowing slightly to bronze (5E5) (ISCC 58) hair brown (5E4) (ISCC 80) clay (5D5) (ISCC 76) or beige (4C3) (ISCC 90), uniformly colored, or else the disc colored as above and the margin fading to ivory (4B3) (ISCC 90) or cream (4A3) (ISCC 89); context thickish (3-6 mm on disc), white, hygrophanous and cinereous under cuticle, soft, fragile; odor faintly amygdaline; taste mild at first, then rather unpleasant and persistent. Lamellae adnate or sinuate young, yellowing slightly with age, subdistant, becoming moderately broad (1.5-6 mm), thickish, edges even. Stipe 2-8 cm long, 4-13 mm thick at apex, white at first, staining pale cinereous to beige with age and handling, white within, evenly pruinose-fibrillose overall at first, later pruinose only at apex and glabrous to appressed-fibrillose below, the apical ornamentation yellow in KOH, the lower stipe not reacting; dry or moist, never viscid, equal or slightly narrowed towards apex, terete or subcompressed, often slightly twisted, solid.

Microscopic Structures: Spores 7-11 x (4)4.5-6(7.5) μm , ellipsoidal to oblong, smooth, inamyloid. Basidia 38-59 x 6.5-10 μm , narrowly clavate, 4-spored, the sterigmata prominent, up to 5 μm long. Pleurocystidia and cheilocystidia absent. Gill trama divergent from a thin, obscure central strand, the hyphae 3-16 μm broad. Cuticle an ixotrichodermium 215-345 μm thick, a broad zone of tangled, branched, generally erect, gelatinous hyphae, slender, not forming a palisade. Pileal trama of radial, slightly interwoven hyphae. No hypodermium seen. Apical stipe with projecting fasciculate hyphae with cystidioid terminal cells, clavate to cylindric, or bulbous at apex, 21-60 x 8-12 μm . Clamp connections small and nub-like, on hyphae of cuticle, gill trama, and pileal trama.

Habit and Habitat: Scattered to gregarious, at times subcespitose, in grass or moss in coniferous woods, particularly under spruce and hemlock. Frequent.

Material Studied: ACAD 12280, Gaspereau Valley, Kings Co., 29 Oct. 1968; ACAD 12283, 12287, 12288, North Mountain, Kings Co., 29 Oct. 1968.

Remarks: The viscid, grayish pileus, the amygdaline odor, and the dry, white or cinerescent stipe distinguish this species. Small specimens might be confused with *H. tephroleucus* var. *tephroleucus*, in which the slightly viscid stipe is soon dry and the pileus is also viscid with the same grayish color. However, *H. tephroleucus* lacks a distinctive odor, and the mature stipe is ornamented with definite brownish punctae instead of cinereous streaks and patches as in *H. agathosmus*.

Hygrophorus agathosmus can also resemble *H. odoratus*, but the mature pileus of the former does not develop yellow tints and the spores are slightly smaller. For a more detailed comparison of the two, see *H. odoratus*.

32. *Hygrophorus odoratus* Sm. & Hes.

Sydowia 8: 310. 1954.

Figs 69, 70.

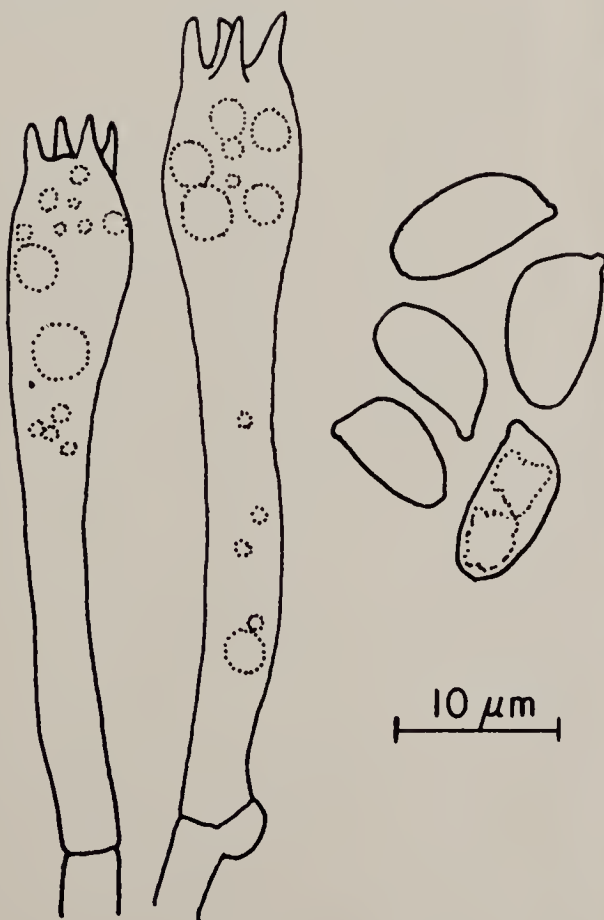
Basidiocarp: Pileus 0.5-4 cm broad, broadly conic to obtuse young, becoming convex to plane, usually with a small, obtuse umbo, occasionally depressed, viscid when fresh, drying glabrous and dull, margin slightly crenate in age, ash blond (3C3) (ISCC 90), beige (4C3) (ISCC 90), bamboo (4C4) (ISCC 90), drab (5E3) (ISCC 80), or hair brown (5E4) (ISCC 80), grayish when young, with yellow tints in age, generally darker on disc; context thin (2-5 mm thick on disc), white, spongy; odor strongly aromatic, of daisies, persisting in recently dried specimens; taste insipid. Lamellae broadly adnate or short-decurrent, white, flushed orange-white (5A2) (ISCC 73) in age, thickish, subdistant, moderately broad (1-6 mm). Stipe 1-7.5 cm long, 2-10 mm thick at apex, white above, yellowish below, especially after handling, white within, glabrous, pruinose, or minutely scabrous above, glabrous below, not viscid, long-ventricose young, equal or slightly narrowed above at maturity, occasionally subcompressed, at times flexuous, loosely stuffed to solid.

Figs 66-68. *H. agathosmus*. Fig 66. ACAD 12283, X .75. Fig 67. ACAD 12280, basidia and spores; redrawn by permission of the National Research Council of Canada from the *Canadian Journal of Botany*, 48, pp. 403-411. 1970. Fig 68. ACAD 12283, surface hyphae of apical stipe, with projecting cystidioid terminal cells.

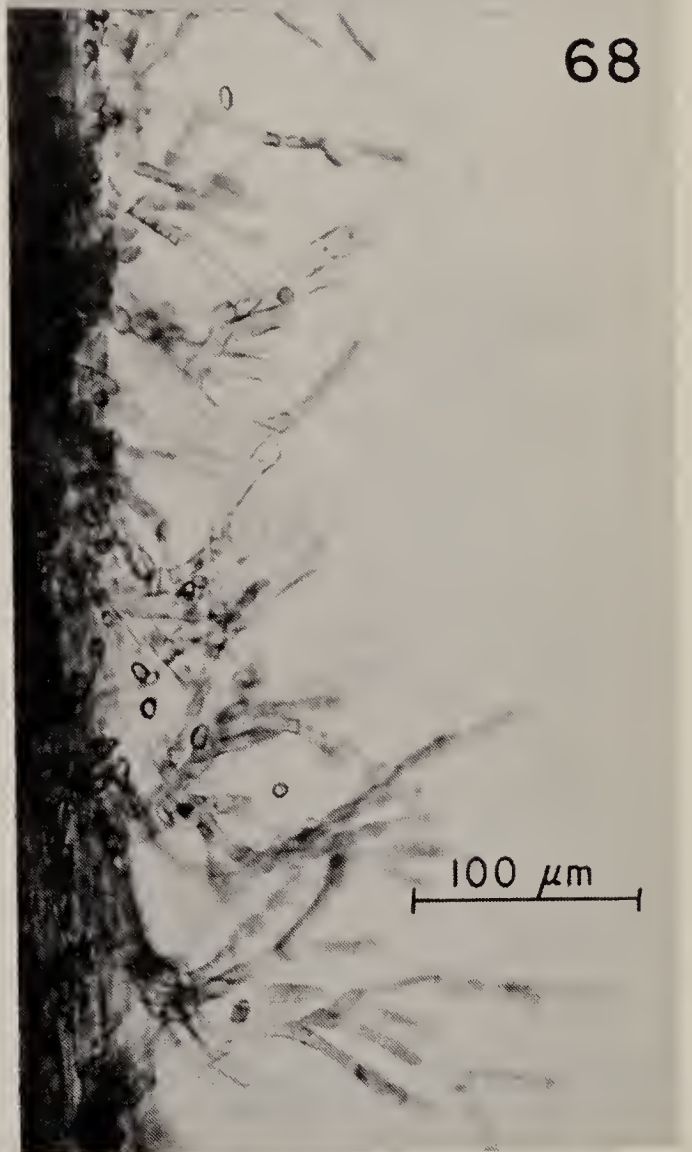
66



67



68





70



Figs 69, 70. *H. odoratus*. Fig 69. ACAD 12269, X 1.0. Fig. 70. ACAD 12269, basidia and spores; redrawn by permission of the National Research Council of Canada from the *Canadian Journal of Botany*, 48, pp. 403-411. 1970.

Microscopic Structures: Spores 9.5-12.5(14) x 6-8(8.5) μm , short-elliptical to obovate, occasionally subglobose, smooth, inamyloid. Basidia 49-66 x 7.5-13.5 μm , narrowly clavate, at times inflated and rather stout, 4-spored, the sterigmata stout, up to 6 μm long. Pleurocystidia and cheilocystidia absent. Gill trama divergent. Cuticle an ixocutis 170-260 μm thick, the hyphae gelatinized, roughly radial, repent, some branched or reflexed, light brown, narrow, arising from a compact layer of darker brown, broader hyphae transitional to the context. Pileal trama radial and slightly interwoven; hypodermium absent. Clamp connections on hyphae of cuticle, gill trama, and pileal trama.

Habit and Habitat: Scattered to gregarious in coniferous woods.

Material Studied: ACAD 12267, Aspen, Guysborough Co., 14 Oct. 1968; ACAD 12260, 12268, Blue Mountain, Pictou Co., 14 Oct. 1968; ACAD 12269, Denver, Guysborough Co., 14 Oct. 1968.

Remarks: This species closely resembles *H. pacificus* in odor, stature, and spore size, but differs in the gray-brown pileus and the tinge of yellow in age. *H. pacificus* is russet to tawny, fading pinkish buff on the margin when old.

In the field, *H. odoratus* might be mistaken for a slender form of *H. agathosmus*, which we find has a distinctly amygdaline odor when fresh, and smaller spores. Moreover, *H. agathosmus* fails to develop yellow tints on the pileus, although the typical gray tends to alter to brownish in old, dry specimens. Also, the stipe of *H. odoratus* becomes yellowish on handling, while the stipe of *H. agathosmus* is cinerescence.

Section LIGNICOLOHYGROPHORUS sec. nov.

Sporocarpia lignatilia; trama lamellarum subparallela; hyphae contexti dimiticae, interdum parietibus crassis; sporae inamyloideae.

Species typica: *H. lignicola* sp. nov.

Sporocarps lignicolous; lamellar trama subparallel; context with scattered thick-walled hyphae; spores white, smooth, inamyloid.

33. *Hygrophorus lignicola* sp. nov.

Figs 71, 72, 73.

Pileus 3-4 cm latus, planoconvexus et parum depressus, siccus, pruinotomentosus, cremeus, demum stramineus; caro albida, solida et plus minusve cohaerens, odore leviter aromatico, sapore parum ingrato. Lamellae uncinatae, albidae, subdistantes. Stipes 4 cm longus, 8 mm crassus, siccus, tomentosus, eburneus, deorsum cremeus, ubi traceaeus atrans, solidus. Sporae 7-10(11) x 3.5-4 μm , ellipsoideae, inamyloideae. Hyphae in trama pilei et stipitis dimiticae, pro parte maxima 3-10.5 μm latae parietibus tenuis; aliquot hyphae 4.5-8 μm latae, vix septatae, parietibus crassis, diametro irregulari.

Holotypus ACAD 12222, lignatilis, prope Sunken Lake, comitato Kings, Nova Scotia lectus, in herbario Universitatis Acadiensis conservatus.

Basidiocarp: Pileus 3.4 cm broad, planoconvex and slightly depressed, dry, pruinose-tomentose on disc, the tomentum thinning peripherally, pallid cream, darkening to cream (4A3) (ISCC 89) and pallid yellow towards the margin; context thick (5 mm) on disc, white, tinged pale yellow under the cuticle, unchanging, firm, slightly rubbery; odor faintly aromatic, of caraway; taste slightly unpleasant. Lamellae broadly adnexed and uncinatae, almost subdecurrent, white, moderately broad (3.5 mm), subdistant, thickish, intervenose in places and especially near the stipe, edges even. Stipe 4 cm long, 8 mm thick at apex, white above, gradually pallid beige downward, darkening where handled, dry, obscurely and irregularly reticulate where the gills

join, grading downwards to short-tomentose, becoming soft-hirsute below, the mycelial hairs collapsing and forming a tomentum on handling, unchanging in KOH, equal; context white, solid, soft and rubbery.

Microscopic structures: Spores 7-10(11) x 3.5-4 μm , ellipsoidal, smooth, inamyloid. Basidia 30-48 x 5-7 μm , clavate, slender, 4-spored, the sterigmata up to 8 μm long. Pleurocystidia and cheilocystidia absent. Gill trama subparallel, flanked by a narrow, small-cell subhymenium, dimitic: mostly of thin-walled hyphae 3-9 μm broad, rather uniform, with frequent septa, at times crossing the trama at right angles; plus some scattered thick-walled, sparingly septate hyphae. Cuticle a layer up to 175 μm deep of colorless, interwoven, roughly radial, nongelatinous hyphae, little demarcated from the context. Pileal trama interwoven, dimitic; most of the hyphae thin-walled, 3-10.5 μm broad, with slightly irregular diameters and frequent septa; a few hyphae thick-walled, 4.5-8 μm broad, more irregular in diameter and sparsely septate. Clamp connections present in the cuticle, gill trama, and pileal trama.

Habit and Habitat: Solitary, on recently fallen sugar maple *Acer saccharum* Marsh. Rare.

Material Studied: ACAD 12222 (holotype), Sunken Lake, Kings Co., 8 Oct. 1968.

Remarks: This *Hygrophorus* is unique in its lignicolous habit and the thick-walled hyphae scattered in its lamellar and pileal tramas. Both features are more characteristic of the *Tricholomataceae*, but the thick, sharp-edged, waxy lamellae and the long, slender basidia are diagnostic features of the *Hygrophoraceae* (Smith & Shaffer 1964; Shaffer 1968).

The parallel lamellar trama and smooth, inamyloid spores would ordinarily place this species in section *Hygrocybe*, but the fungus is not one of the terrestrial, fragile, waxy and hygrophane species that constitute this section. Its general appearance is more reminiscent of Section *Hygrophorus*. Thus, a new section, *Lignicolohygrophorus*, is proposed to accommodate it.

Section HYGROCYBE Fr.

Epicr. Myc., p. 329, 1838.

Lamellar trama parallel to slightly interwoven; pileal cuticle not hymeniform or cellular; spores smooth, inamyloid; hymenial cystidia occasionally present; clamp connections present or absent; sporocarps terrestrial, fragile, and often brightly colored.

Type species: *H. miniatus* (Fr.) Fr.

Subsection PSITTACINI Bataille

Flora Monogr. Hygrophores, p. 50. 1910.

Pileus and stipe viscid.

Type species: *H. psittacinus* (Fr.) Fr.

71



72



73

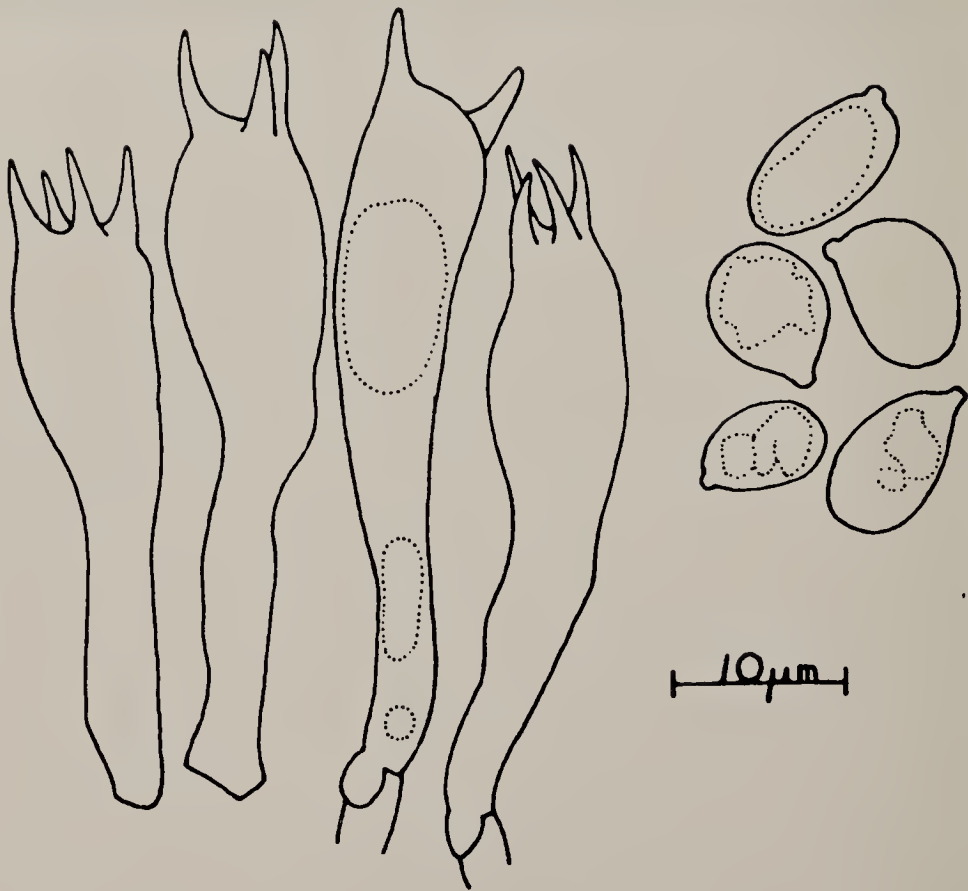


10μm

74



75



Series PURI Hes. & Sm.

N. Am. Spec. of *Hygrophorus*, p. 214. 1963.

Pileus conic.

Type species: *H. purus* Pk.

34. *Hygrophorus ruber* Pk.

N. Y. State Mus. Bull. 116: 32. 1907.

Hydrocybe ruber (Pk.) Murr., N. Am. Flora 9: 379. 1916.

Figs 74, 75.

Basidiocarp: Pileus 0.5-2.5 cm broad, sharply to broadly conic, becoming almost plane with a small, acute umbo, margin persistently incurved, viscid when fresh, eventually dry and shining, glabrous, margin at times translucent-striate moist, scarlet, fading to orange and yellow-orange, not blackening when injured or dried; context thin (to 2.5 mm on disc), fragile, light yellow, or hygrophanous and concolorous with the surface, unchanging; odor and taste not distinctive. Lamellae adnexed and seceding, or adnate and becoming deeply emarginate with a decurrent tooth, pallid yellow, often flushed pale orange when young, broad (2-4 mm), subdistant to close, thickish, brittle, edges even or eroded. Stipe 2.5-6.5 cm long, 2-5.5 mm thick at apex, yellow-orange to orange above, paling to yellow or whitish below, pallid yellow within, very briefly viscid, soon resinous to moist, glabrous, slender, equal or long-ventricose, terete or slightly compressed, stuffed, becoming hollow.

Microscopic Structures: Spores 7.5-12.5 x (4)4.5-8 μm , shape variable in one gill, generally elliptical to oblong, often obovate, occasionally subglobose, smooth, inamyloid. Basidia 29-48 x 7-11.5 μm , long-clavate, relatively short, mostly 4-spored, less frequently 1-, 2-, and 3-spored in the same gill, sterigmata up to 7(10.5) μm long. Pleurocystidia and cheilocystidia absent. Gill trama parallel, of long-celled, scarcely interwoven hyphae. Cuticle an ixocutis 43-345 μm deep, difficult to demonstrate except in fresh, appreciably viscid pilei, the hyphae 1.7-7 μm broad, radial, repent or slightly reflexed, branched, gelatinous to subgelatinous. Pileal trama of radial, parallel hyphae, sparsely septate like the gill tramal hyphae, yellow-red to yellow-brown under cuticle, colorless over hymenium. Stipe surface of narrow, sparse, tangled, subgelatinous hyphae merging with the parallel context hyphae. Clamp connections present on the hyphae of the cuticle and gill trama, rare or absent on the hyphae of the pileal trama and stipe.

Habit and Habitat: Gregarious in mixed woods.

Material Studied: ACAD 12250, 12270, Moose River, Pictou Co., 14 Oct. 1968.

Remarks: *Hygrophorus ruber* resembles *H. conicus* in shape, color, and structure of the gill trama, but differs in its slightly viscid, non-striate stipe and its persistent, unchanging colors. *H. cuspidatus* Pk. (not in Nova Scotia) is similar in its unchanging red color and conic pileus but has a dry, striate stipe.

Peck's (1907) original description gave the spore size as .00024-.0003 x .00016-.0002 in (6-7.5 x 4-5 μm). Hesler and Smith (1963) found the spores to be 7-9 x 4.5-6 μm . In our material, they were even larger, presumably because of the presence of 1-, 2-, and 3-spored basidia.

Figs 74, 75. *H. ruber*. Fig 74. ACAD 12381. X 1.5. Fig 75. ACAD 12250, basidia and spores. Figs 74, 75 reproduced by permission of the National Research Council of Canada from the *Canadian Journal of Botany*, 52, pp. 1243-1247, 1974, and 48, pp. 403-411, 1970, respectively.

The gelatinous layers on the stipe and pileus are poorly organized and difficult to demonstrate in sections of dried material.

Series PSITTACINI

Pileus convex to depressed, some shade or red, yellow or green; stipe and pileus viscid; lamellar trama parallel.

35. *Hygrophorus psittacinus* (Fr.) Fr. var. *psittacinus*

Epicr. Myc., p. 332. 1838.

Agaricus psittacinus Fr., Syst. Myc. 1: 102. 1821.

Hygrocybe psittacina (Fr.) Kummer, Führ. in Pilzk., p. 112. 1871.

Hydrocybe psittacina (Schaeff. ex Fr.) P. Karst., Bidr. Finl. Nat. Folk 32: 237. 1879.

Figs 76, 77.

Basidiocarp: Pileus 0.5-3.5 cm broad, hemispheric or broadly conic young, becoming convex to plane, sometimes remaining subumbonate, glutinous to viscid, glabrous beneath the gluten, margin striate when moist, dark olive or brownish green at first, rarely pale green (27A3) (ISCC 148), very soon fading apricot yellow (5B6) (ISCC 76) to pale orange (5A3) (ISCC 73), generally retaining some green tints at the margin, drying yellow-orange to pinkish orange; context thin (1-2 mm on disc), concolorous with the pileus or paler, eventually whitish, fragile; odor and taste not distinctive. Lamellae variously attached, broadly adnexed to adnate, at times emarginate to uncinete, often seceding, olivaceous at first, fading to dull yellow, yellow-orange, or dingy orange buff, persistently olivaceous at the edges, subdistant, thickish, narrow to broad (1-5 mm), edges even. Stipe 0.5-5.5 cm long, 1.5-4 mm thick, olive green at apex, pale yellow to melon yellow (5A6) (ISCC 70) below, whitish at extreme base, viscid to lubricous overall, soon drying, equal or slightly expanded above, terete or apically subcompressed; context whitish at apex, elsewhere concolorous with the exterior, hollow.

Microscopic Structures: Spores 6-9.5(12) x 4-6 μ m, obovate to short-elliptical, smooth, inamyloid. Basidia 24-50 x 6-10.5 μ m, narrowly clavate, mostly 4-spored with 3-, 2-, and 1- spored basidia present in varying proportions in the same gill, the sterigmata slender, up to 8(14.5) μ m long. Pleurocystidia and cheilocystidia absent. Gill trama of subparallel, inflated hyphae 7-24 μ m broad. Cuticle an ixotrichodermium 70-130 μ m deep, the hyphae gelatinous, 1.2-3 μ m broad, erect, branched, the terminal elements cylindrical to subclavate, forming a palisade on a substratum of similar, interwoven hyphae. Pileal trama of radial, subparallel hyphae; hypodermium absent. Clamp connections common in the subhymenium, less frequent in the cuticle, the gill trama, and the pileal trama.

Habit and Habitat: Solitary to gregarious in boggy areas, in grass, or in leaf mold in mixed or deciduous woods. Frequent.

Material Studied: ACAD 12105, ravine, Agriculture Experimental Station, Kentville, Kings Co., 29 Sept. 1967; ACAD 12108, Grand Anse Valley, Inverness Co., 7 Oct. 1967; ACAD 12175, Aylesford Lake, Kings Co., 30 Aug. 1968; ACAD 12143, Hebb's Cross, Lunenburg Co., 14 July 1968; ACAD 12157, Hebb's Cross, Lunenburg Co., 9 Aug. 1968.

Remarks: *Hygrophorus psittacinus* var. *psittacinus* is recognized by the bright olive green color which quickly fades to yellow-orange. The persistently green gill edges and stipe apex distinguish this species from young, olive-tinged specimens of *H. laetus*. However, all traces of green disappear in the drying process, and dried sporocarps of the two species are macroscopically identical.

76



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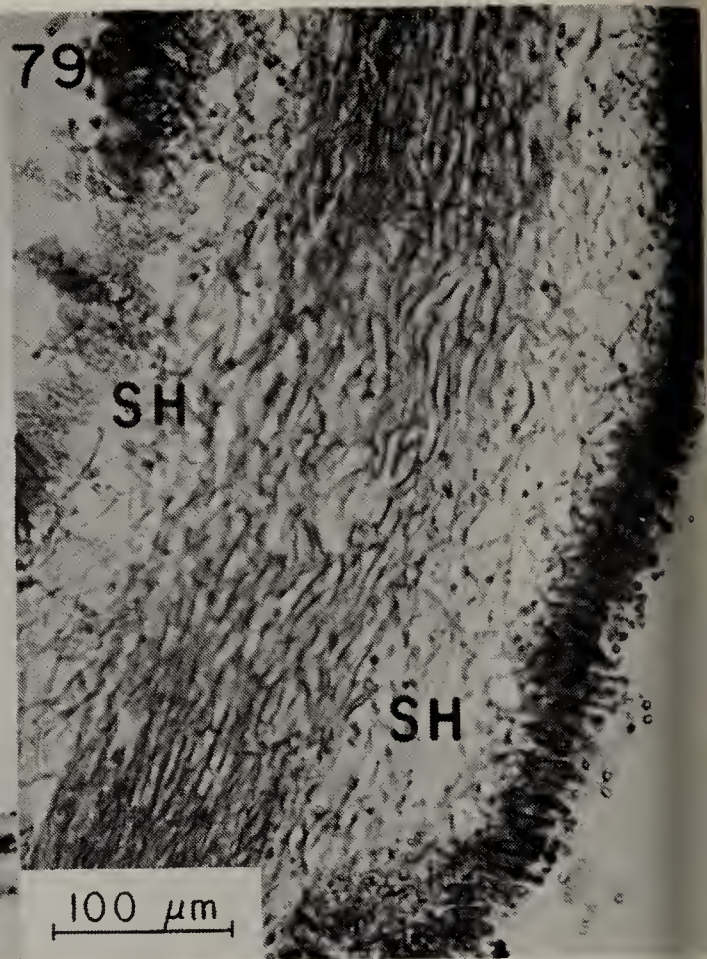


Figs 76, 77. *H. psittacinus* var. *psittacinus*. Fig 76. ACAD 12143, X 1.25. Fig 77. ACAD 12108, basidia and spores.

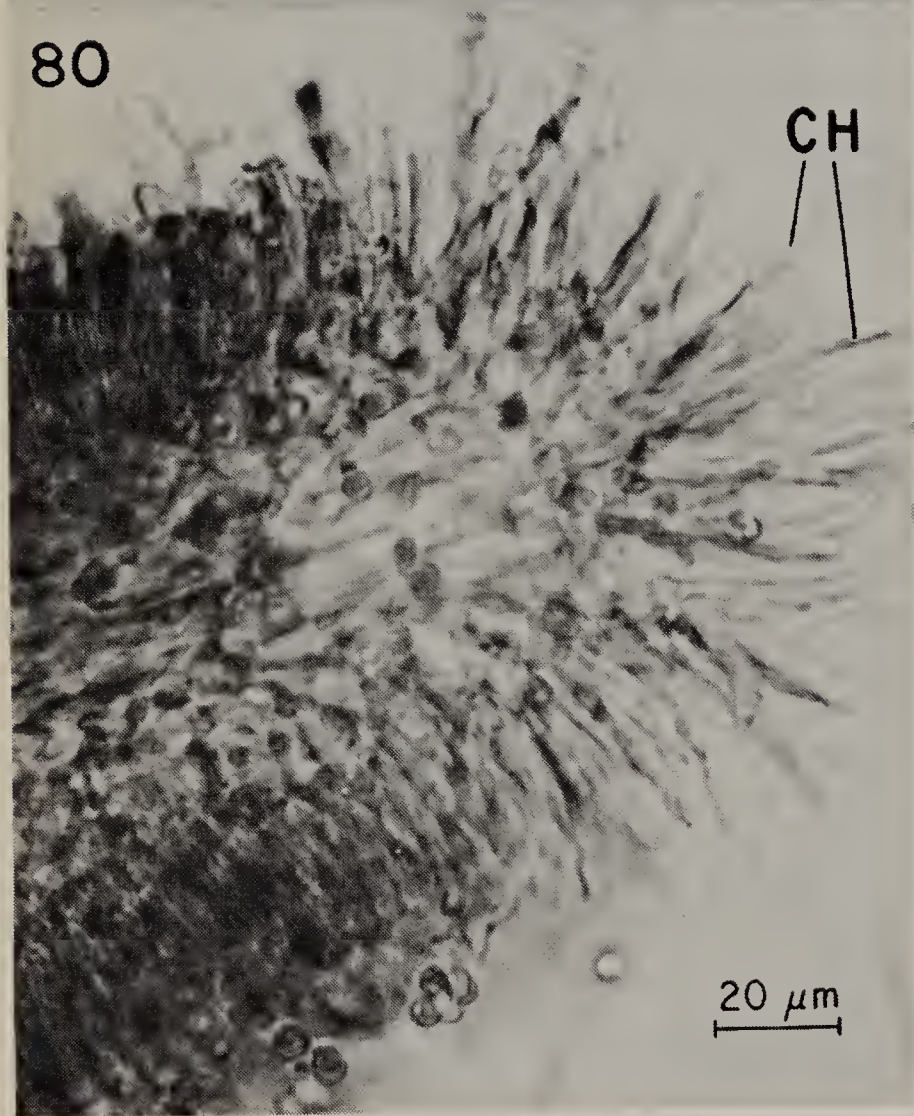
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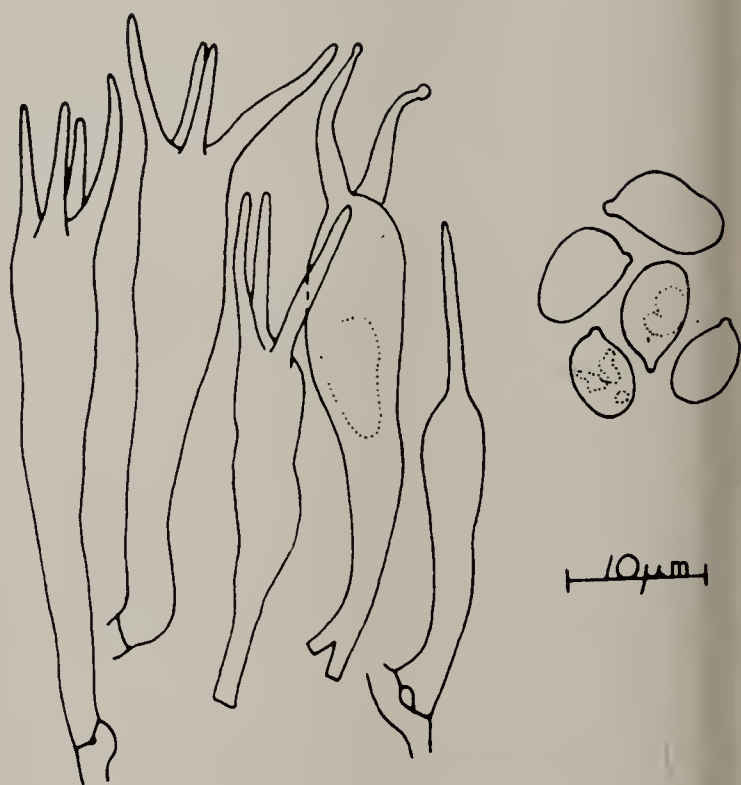
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36. **Hygrophorus laetus (Fr.) Fr.***Epicr. Myc.*, p. 329. 1838.*Agaricus laetus* Fr., *Syst. Myc.* 1: 102. 1821.*Hygrocybe laeta* (Fr.) Kummer, *Führ. in Pilzk.*, p. 112. 1871.*Hygrophorus peckii* Atk., *J. Myc.* 8: 114. 1902.*Hygrophorus davisii* Pk., *Bull. Torrey Bot. Club* 33: 214. 1906.*Hydrocybe davisii* (Pk.) Murr., *N. Am. Flora* 9: 382. 1916.*Hydrocybe roseiceps* Murr., *Lloydia* 5: 138. 1942.*Hygrophorus roseiceps* Murr., *Lloydia* 5: 157. 1942.

Figs 78, 79, 80, 81.

Basidiocarp: Pileus 0.5-3.5 cm broad, hemispheric or obtuse young, later convex, usually centrally depressed or umbilicate, finally plane and depressed, margin often wavy, glutinous to viscid, drying with a dull gloss, glabrous, margin translucent-striate moist, carrot red (6A7) (ISCC 50) tinged with sordid olive when young, soon fading to apricot yellow (5B6) (ISCC 76) or melon yellow (5A6) (ISCC 70) on disc, and pale orange (5A3) (ISCC 73) to cream (4A3) (ISCC 89) on the margin, sometimes with a slight vinaceous tinge, drying pale pinkish orange to yellow-orange; context thin to membranous, (up to 1.5 mm thick on disc), whitish to pale yellow-orange, pinkish orange, or yellow, fibrous, fragile; odor mephitic or resembling tulips; taste not distinctive or else mildly disagreeable. Lamellae short-decurrent to decurrent, at times adnexed and uncinat, at first pale vinaceous, yellow-orange, or sordid olivaceous, later cream (4A3) (ISCC 89), pallid buff, or peach, lacking the olive tinge, waxy, subdistant, edges even. Stipe 1.5-7(10.5) cm long, 1-4 mm thick at apex, apricot yellow (5B6) (ISCC 76), amber yellow (4B6) (ISCC 87), maize yellow (4A6) (ISCC 83), or butter yellow (4A5) (ISCC 86), sometimes light brown (6D8) (ISCC 54), rarely brick red (7D7) (ISCC 43), gradually pinkish livid to pinkish buff above, whitish or hygrophanous within, glutinous to resinous, glabrous, or rarely with conspicuous, reticulate striae over the lower part, equal or long-ventricose, or slightly expanded above, straight or slightly flexuous, stuffed at first, then hollow.

Microscopic Structures: Spores 6-9.5(10) x 4-5(6) μm , short-elliptical, sometimes lacrimoid with attenuated apicular end, smooth, inamyloid. Basidia 21-43(55) x (3.5)4-6.5(8) μm short and clavate to slender and flexuous, often bipedal, mostly 4-spored, occasionally to frequently 2- and 3-spored in the same gill, rarely 1-spored, the sterigmata very long and slender, especially near the gill edge, up to 17.5 μm long. Pleurocystidia absent. Cheilocystidia filiform and gelatinous (examine entire gill fragment under low power), 21-46 x 1-3 μm . Gill trama a central strand of yellow, subparallel hyphae flanked by equally broad gelatinous subhymenium of interwoven, narrower hyphae. Cuticle an ixotrichodermium 130-350 μm deep, the hyphae generally erect, branching, not forming a palisade, gelatinous, 1-3.5 μm broad, usually irregular from scattered protuberances and bulges. Stipe surface similar to pileal cuticle. Pileal trama of radial, parallel hyphae 9-25 μm broad. Clamp connections present in the subhymenium, infrequent in the cuticle and gill trama, not seen in the pileal trama.

Figs 78-81. *H. laetus*. Fig 78. ACAD 12176, X .65. Fig 79. ACAD 12176, section of lamellar trama showing parallel mediostratum and broad, gelatinous subhymenium (SH). Fig 80. ACAD 12153, section of lamella showing filiform cheilocystidia (CH). Fig 81. ACAD 12176, basidia and spores.

Habit and Habitat: Scattered to gregarious, rarely solitary, in *Sphagnum* bogs and adjacent, moist grassy areas, leaf mold, or among other mosses. Common.

Material Studied: ACAD 12150, Aylesford Lake, Kings Co., 30 July 1968; ACAD 12153, Hebb's Cross, Lunenburg Co., 4 Aug. 1968; ACAD 12162, Hebb's Cross, Lunenburg Co., 9 Aug. 1968; ACAD 12170, 12171, Aylesford Lake, Kings Co., 23 Aug. 1968; ACAD 12176, Aylesford Lake, Kings Co., 30 Aug. 1968; ACAD 12179, Lake Woods, Kentville, Kings Co., 29 Aug. 1968; ACAD 12180, ravine, Agriculture Experimental Station, Kentville, Kings Co., 10 Sept. 1968.

Remarks: Olive-tinged pilei of young sporocarps might be confused with those of *H. psittacinus* var. *psittacinus*, but the unmistakable mephitic odor, the gelatinous subhymenium, and the gelatinous, filiform cheilocystidia distinguish *H. laetus* from this and all other members of Section *Hygrocybe*. The livid stipe apex, when it occurs, is another distinctive feature.

Hydrocybe laeta (Pers.) P. Karst., as cited by Murrill (1916), differs too radically to be considered a synonym.

37. *Hygrophorus minutulus* Pk.

N.Y. State Mus. Bull. 1(2): 9. 1887.

Hydrocybe minutula (Pk.) Murr., N. Am. Flora 9: 380. 1916.

Figs 82, 83.

Basidiocarp: Pileus 0.5-2 cm broad, at first convex becoming plane; surface glabrous, viscid, glutinous when wet, margin striatulate; color bright reddish orange or scarlet (ISCC 34) becoming vivid orange (ISCC 48) and sometimes deep orange (ISCC 51); context thin, orange; taste and odor not distinctive. Lamellae adnexed to adnate, close, becoming subdistant at maturity; color light orange (ISCC 67). Stipe 2-5 cm long, 1-3 mm thick, tapering toward base; surface glabrous, viscid to glutinous when wet; red (ISCC 36) at apex, fading to yellow or pallid at base; context soft, stuffed when young, becoming hollow.

Microscopic Structures: Spores 7-9.5(10.5) x 4-6.5 μ m, ellipsoidal or slightly broadened at apicular end, smooth, inamyloid. Basidia 29-47 x 6.5-10.5 μ m, mostly about 33 x 7 μ m, narrowly clavate, rather short for the spore size, 4-spored, the sterigmata up to 6 μ m long, slender, often with rounded tips. Pleurocystidia and cheilocystidia absent. Gill trama of subparallel, scarcely inflated hyphae 3-14 μ m broad. Cuticle an ixocutis 50-140 μ m deep, the hyphae 1.7-5.5 μ m broad, gelatinous, generally radial and repent but frequently reflexed or erect. Pileal trama of radial, subparallel, scarcely inflated hyphae 4.5-21 μ m broad; hypodermium absent. Clamp connections present in the cuticle and gill trama, not seen in the pileal trama.

Habit and Habitat: Gregarious in grass. Rare.

Material Studied: ACAD 6263, Kentville, Kings Co., 30 Aug. 1956.

Remarks: The distinguishing features of *H. minutulus* are its convex, viscid, red pileus and its red to yellow, viscid stipe. The colors persist in dried material.

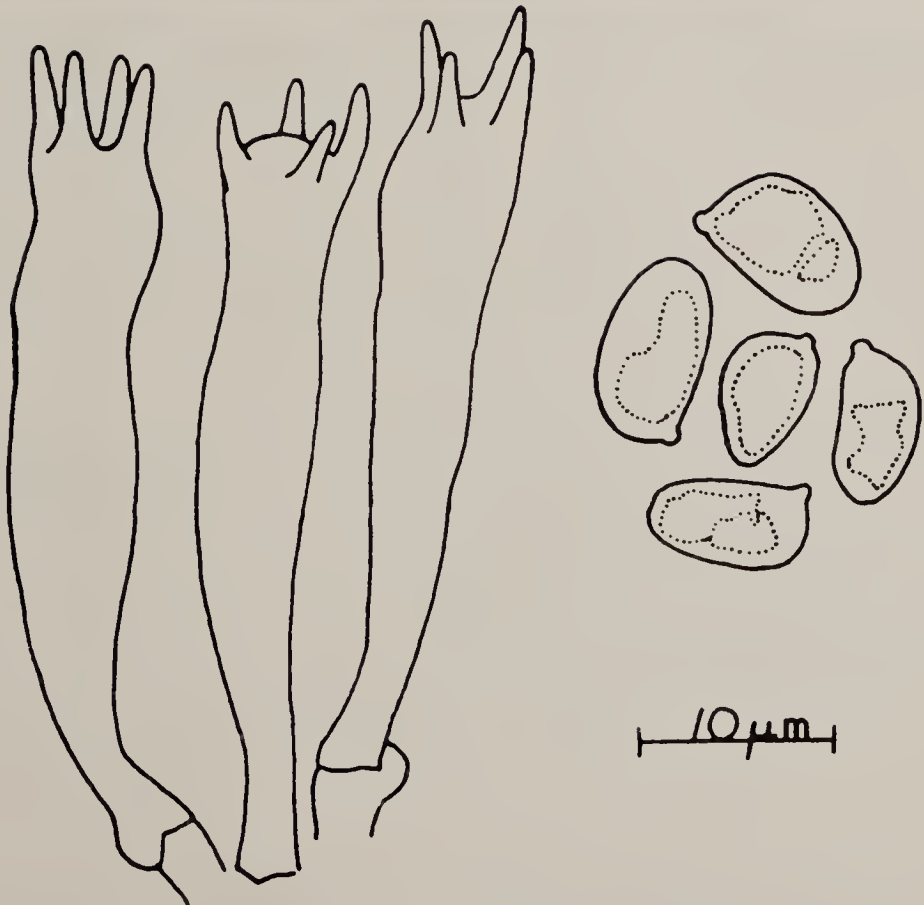
Peck (1907) described the lamellae as whitish, tinged with red or yellow. He also described the stipe as solid, and therefore inconsistent with the general characteristics of Subgenus (now Section) *Hygrocybe*.

Figs 82, 83. *H. minutulus*. Fig 82. Smith 2835 b, X 1.0; from *North American Species of Hygrophorus*, by L.R. Hesler and A. H. Smith, (c) 1963 by the University of Tennessee Press, Knoxville; reprinted by permission of the University of Tennessee Press. Fig 83. ACAD 6263, basidia and spores.

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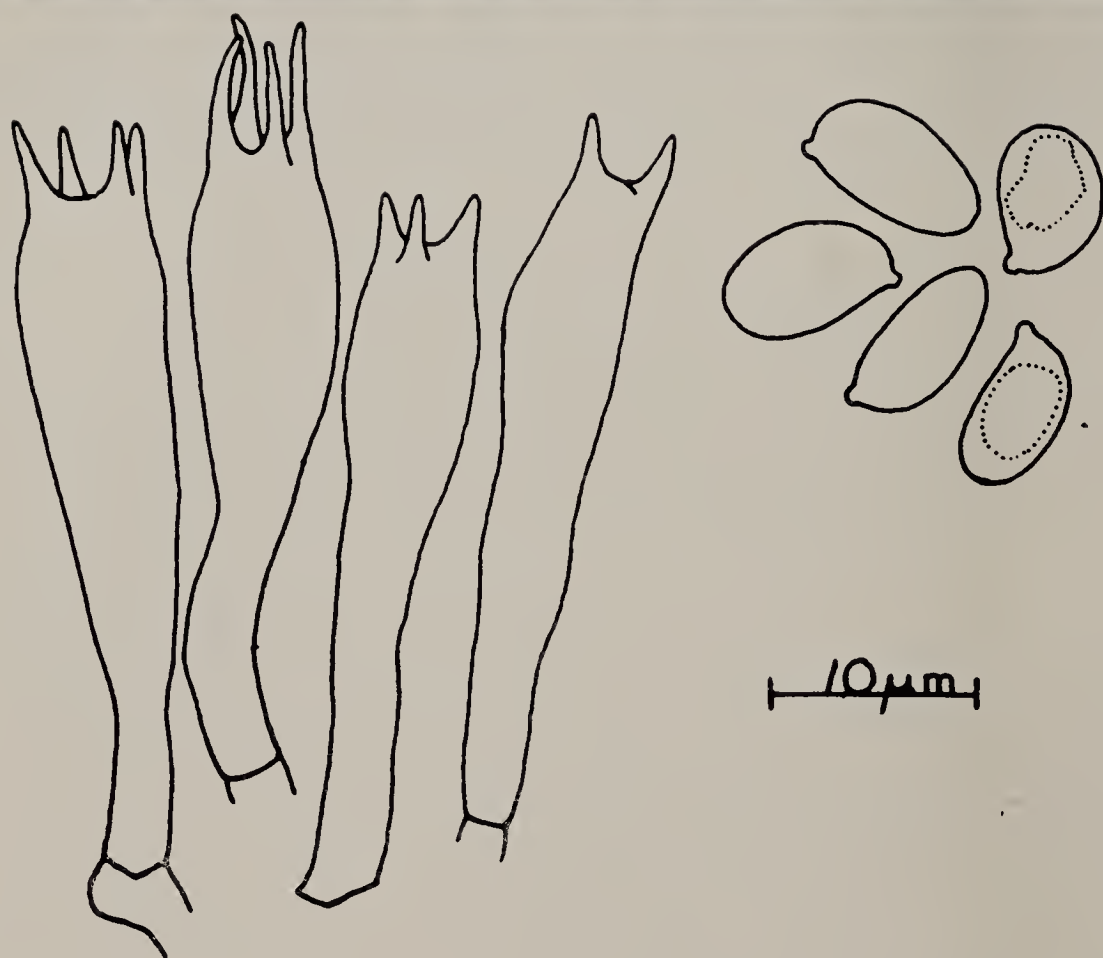


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Figs 84, 85. *H. nitidus*. Fig 84. ACAD 12147, X 1.0. Fig 85. ACAD 12164, basidia and spores.

38 *Hygrophorus nitidus* B. & C.

Ann. Mag. Nat. Hist. 2(12): 424. 1853.

Hydrocybe nitida (B. & C.) Murr., N. Am. Flora 9: 378. 1916.

Figs 84, 85.

Basidiocarp: Pileus 0.3-4 cm broad, at first convex and slightly depressed, with involute margin, soon depressed to subumbilicate, finally infundibuliform but imperforate on disc, margin decurved or spreading, viscid when fresh, glabrous, brownish orange (6C8) (ISCC 54) to dark, golden yellow (5B8) (ISCC 69) when young and fresh, fading to Chinese yellow (4B7) (ISCC 84) to pale yellow (2A3) (ISCC 104), finally whitish; context thin (1-3 mm thick on disc), yellow-orange, fading pallid yellowish, occasionally hygrophanous near surface and over gills, soft, fragile; odor and taste not distinctive. Lamellae subdecurrent at first, soon long-decurrent, cadmium orange (5A8) (ISCC 66) to amber yellow (4B6) (ISCC 87) when young, fading to buttercup yellow (4A7) (ISCC 82) or light yellow, darker than the faded pileus, subdistant to distant, rather thin, narrow becoming broad (0.5-8 mm), at times intervenose near the pileus margin, edges even. Stipe 1.5-6 cm long, 1.5-9 mm thick at apex, more or less concolorous with the pileus but not fading to whitish, slightly paler towards base, pallid yellowish within, viscid, lubricous, or resinous, glabrous, equal or long-ventricose, or slightly expanded above, usually compressed or with median longitudinal sulcus, at times terete, stuffed, soon becoming hollow.

Microscopic Structures: Spores 6-9.5(10) x 4-6(6.5) μm , short-elliptical, rarely subglobose, smooth, inamyloid. Basidia 23-40 x 6-8(10.5) μm , clavate, relatively short, mostly 4-spored, occasionally 3-spored and rarely 2-spored in the same gill, the sterigmata slender, to 7 μm long. Pleurocystidia and cheilocystidia absent. Gill trama of subparallel to slightly interwoven, inflated hyphae 9-38 μm broad, with occasional laticifers 1.5-3 μm broad, the subhymenium not gelatinized. Cuticle an ixotrichodermium 90-175 μm deep, the hyphae 1.2-3.5 μm broad, gelatinous, more or less erect, tangled, not forming a palisade. Pileal trama of radial, roughly parallel hyphae; hypodermium absent. Clamp connections small and inconspicuous, on the hyphae of the cuticle and gill trama.

Habit and Habitat: Solitary, gregarious, or subcespitose in deciduous or coniferous woods; often in mosses, particularly *Sphagnum*; occasionally among *Osmunda* spp in forest swales. Common.

Material Studied: ACAD 12130, Harrington Woods, Kings Co., 8 July 1968; ACAD 12147, 12148, Aylesford Lake, Kings Co., 30 July 1968; ACAD 12161, Hebb's Cross, Lunenburg Co., 9 Aug. 1968; ACAD 12174, Aylesford Lake, Kings Co., 23 Aug. 1968; ACAD 12235, St. Catherine's River, Queens Co., 11 Oct. 1968.

Remarks: *Hygrophorus nitidus* is distinguished by the depressed, viscid yellow pileus which eventually fades to whitish, and the viscid stipe. *H. ceraceus* is similar but does not fade to white. Moreover, the viscid layers of *H. ceraceus* are not as well-organized and obvious as they are in *H. nitidus*, and usually disappear in drying.

Hygrophorus laetus may become yellow-orange like *H. nitidus*, but is usually pinkish-tinged and has a mephitic odor. The pileus is also less depressed than in *H. nitidus* and the margin is not as strongly involute in young specimens. Microscopically, the two species are easily distinguished by the presence of gelatinous subhymenium and filiform cheilocystidia in *H. laetus*.

39. **Hygrophorus ceraceus (Fr.) Fr.**

Epicr. Myc., p. 330. 1838.

Agaricus ceraceus Fr., Syst. Myc. 1: 102. 1821.*Hygrocybe ceracea* (Fr.) Kummer, Führ. in Pilzk., p. 112. 1871.*Hygrocybe nitida* var. *lutea* Murr., Bull. Torrey Bot. Club 66: 159. 1939.

Figs 86, 87.

Basidiocarp: Pileus 1-3 cm broad, at first convex or the disc slightly depressed, becoming planoconvex and subumbonate, finally plane with uplifted margin, slightly viscid fresh, glabrous, margin striate moist, tangerine (6B8) (ISCC 50) to cadmium orange (5A8) (ISCC 66) when moist, fading to buttercup yellow (4A7) (ISCC 82) or genet (3A7) (ISCC 83), often tinged with orange; context thin (1-1.5 mm on disc), yellow, hygrophanous, very fragile; odor and taste not distinctive. Lamellae arcuate-decurrent young, becoming adnate and uncinatate, pallid orange to light yellow, moderately close to subdistant, medium broad (1.5-3 mm), brittle, edges even. Stipe 1.5-3 cm long, 2.5-4 mm thick at apex, concolorous with the pileus, pallid at base, yellow within, subviscid, soon dry, glabrous with a pearly lustre, equal or tapered to base, stuffed, soon becoming hollow.

Microscopic Structures: Spores 6-8.5 x 3-5 μm , variable in shape, elliptical, oblong-elliptical, obpyriform to obovate, smooth, inamyloid. Basidia 18-46 x 3.5-8.5 μm , long-clavate, stout or slender, mostly 4-spored, rarely 2-spored in the same gill, the sterigmata slender, up to 7 μm long. Pleurocystidia and cheilocystidia absent. Gill trama of subparallel or slightly interwoven hyphae 7-29 μm broad. Cuticle a thin, poorly organized ixotrichodermium, the hyphae generally erect and tangled, 2-4.5 μm broad, subgelatinous, scarcely reviving as an ixocutis after drying. Pileal trama of inflated, radial, subparallel hyphae 9-27 μm broad, with a few narrow hyphae 2.5-7 μm broad; hypodermium absent. Clamp connections present in the cuticle, gill trama, and pileal trama.

Habit and Habitat: Scattered to gregarious in moss or on soil, in coniferous or deciduous woods. Infrequent.

Material Studied: Wehmeyer 678, Folleigh (sic) Lake, Colchester Co., 20 July 1931 (MICH., fide A.H. Smith). ACAD 12117, Black River, Kings Co., 1 Nov. 1967.

Remarks: The gelatinous exteriors of the pileus and stipe are thin and poorly organized, and revive little or not at all from the dried state. The ixotrichodermial pellicle, if it persists, is compressed by drying to an ixocutis, while stipe gluten usually cannot be detected at all in dried specimens. Thus, Romagnesi's keys described the stipe of *H. ceraceus* as dry (Romagnesi 1962-63). The disappearance of these viscid layers may cause confusion of this species with *H. parvulus* Pk. (not in Nova Scotia) in series *Coccinei*, which has a dry pileus, a dry, often reddish-tinged stipe, and more decurrent lamellae than *H. ceraceus*.

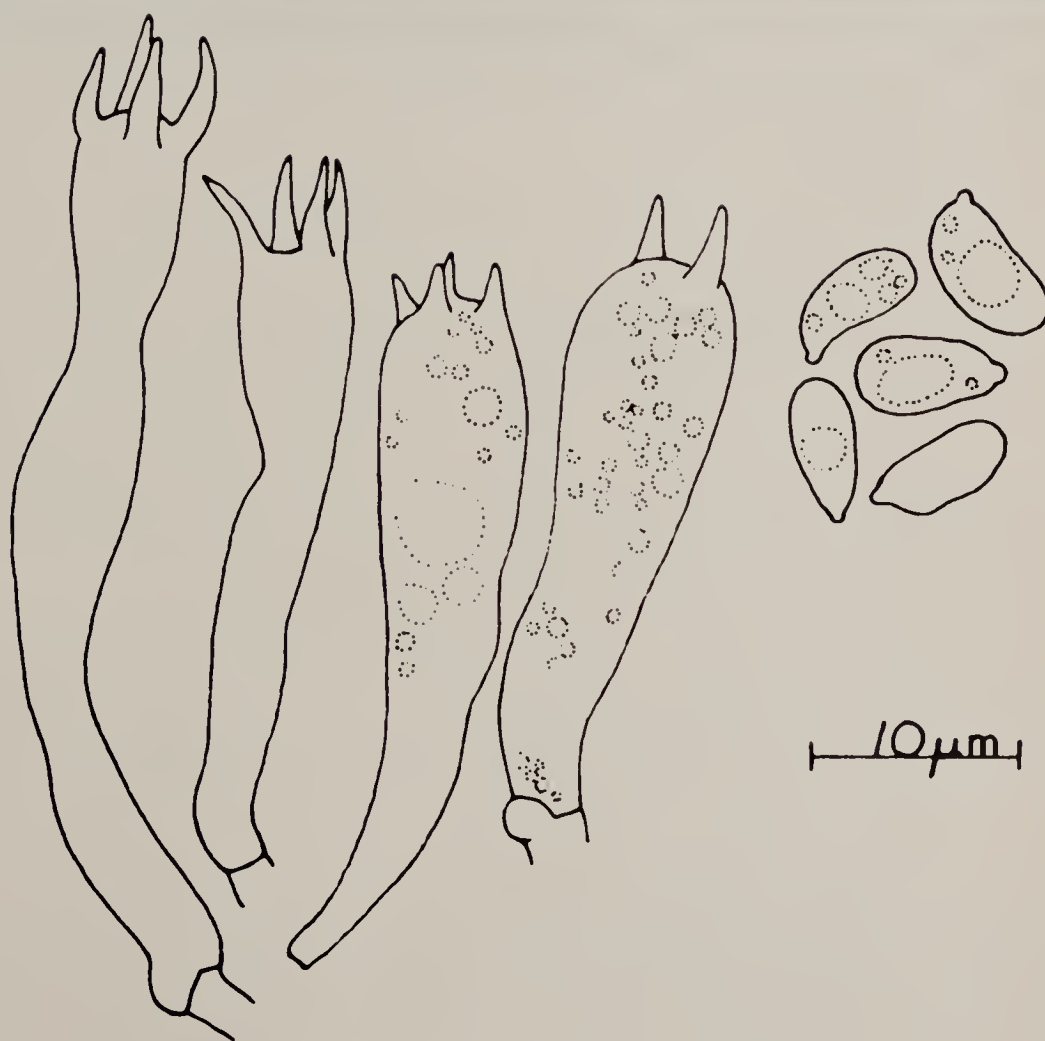
In Series *Psittacini*, *H. ceraceus* is distinguished from the similarly yellow *H. nitidus* by its less depressed pileus and the failure of its pileus to fade whitish with age. *H. nitidus* is also more persistently viscid than *H. ceraceus*.

Kauffman (1918) reported that the lamellar trama of *H. ceraceus* is interwoven, and thus excluded this species from Subgenus (now Section) *Hygrocybe*.

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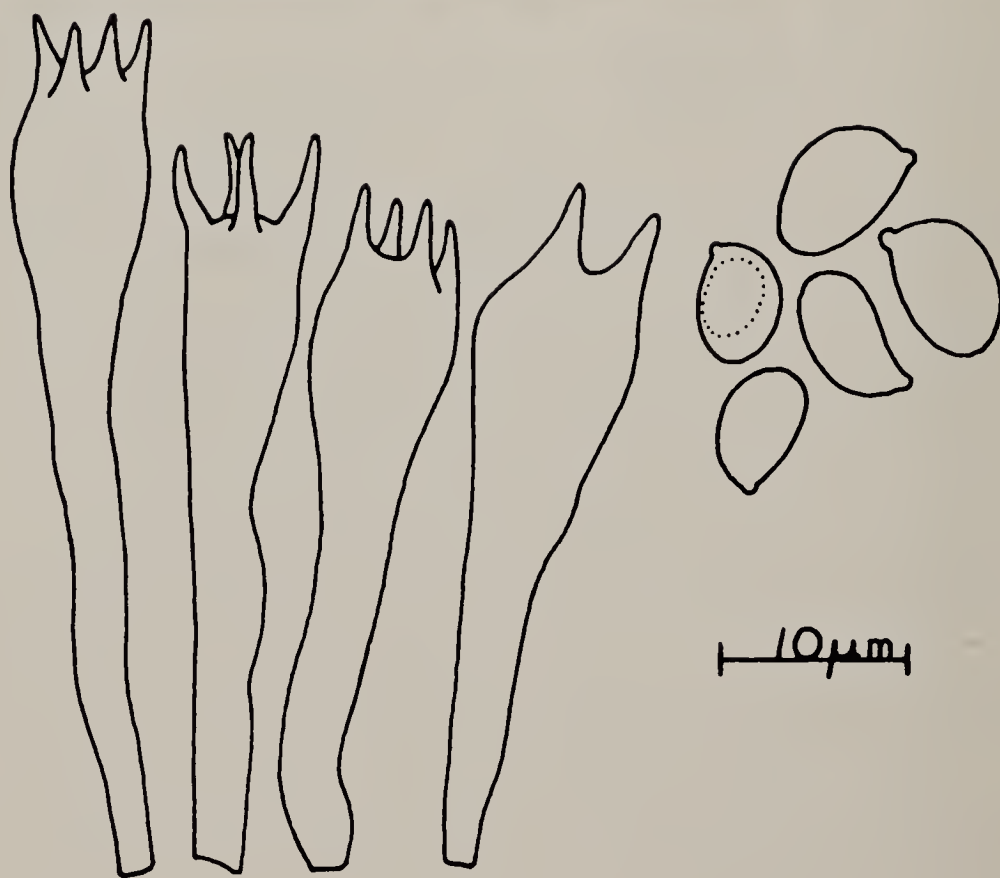


Figs 86, 87. *H. ceraceus*. Fig 86. ACAD 12117, X 1.0. Fig 87. ACAD 12117, basidia and spores.

88



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Figs 88, 89. *H. unguinosus* var. *unguinosus*. Fig 88. Smith 63018, X 1.5. Fig 89. ACAD 8631, basidia and spores.

40. **Hygrophorus chlorophanus (Fr.) Fr.**

Epicr. Myc., p. 332. 1838.

Agaricus chlorophanus Fr. Syst. Myc. 1:103. 1821.*Hygrocybe chlorophana* (Fr) Wünsche. Die Pilze, p. 112. 1877.

"Pileus 2-4 cm broad, convex then expanded, deep lemon yellow, disc at times orange-yellow, viscid, margin striate. Context thin, yellowish; odor and taste mild. Lamellae adnexed, becoming emarginate, whitish to yellowish, rather close, narrow in front. Stipe 3-7 cm long, 4-8 mm thick, viscid, concolorous with the pileus, hollow, glabrous, equal, at times more or less compressed. Spores 6-8 x 4-5 μ , ellipsoid, smooth, yellow in Melzer's reagent. Basidia 34-48 x 5-8 μ , 4-spored. Pleurocystidia and cheilocystidia none. Gill trama parallel, hyphae 8-11(21) μ broad. Lactifers numerous, conspicuously yellow in Melzer's reagent, 3-5 μ broad. Cuticle (an ixocutis) in the form of a thin zone of gelatinous, repent hyphae. No hypodermium differentiated. Pileus trama of radial hyphae. Clamp connections rare on the cuticular hyphae." (Hesler & Smith p. 235, 1963).

Habit and Habitat: "On soil, in open woods . . ." (Hesler & Smith p. 235, 1963).

Remarks: We have not collected this species, and the E.C. Smith Herbarium (ACAD) does not have a specimen. MacKay (1908) first reported it from Halifax County, and Smith and Wehmeyer (1936) later recorded its presence in Colchester County, on bare soil under beech. *Hygrophorus flavescens* has frequently been mistaken for this species (Hesler & Smith 1963), because the stipe of *H. flavescens* tends to become tacky when handled. Therefore, as *H. flavescens* is much more common than *H. chlorophanus*, it is possible that these earlier records may also have been in error. However, K.A. Harrison (in verb.) claims to have seen authentic *H. chlorophanus* in Nova Scotia. Moreover, Hesler and Smith (1963) listed a collection (Bigelow 3142) from Maine; thus, this fungus probably does occur in the province, and we have decided to include it here.

Series INOLENTES (Bataille) Hes. & Sm.

N. Am. Spec. of *Hygrophorus*, p. 218. 1963.

Pileus gray to dull brown, drab; stipe and pileus viscid; lamellar trama parallel.

Type species: *H. unguinosus* (Fr.) Fr.

41. **Hygrophorus unguinosus (Fr.) Fr. var. unguinosus**

Epicr. Myc., p. 332. 1838.

Agaricus unguinosus Fr. Syst. Myc. 101. 1921.*Hygrophorus luridus* B. & C. sensu Coker, J. Elisha Mitchell Sci. Soc. 45: 168.*Hygrocybe unguinosa* (Fr.) Karst. Hattsd. p. 237. 1879.

Figs 88, 89.

Basidiocarp: Pileus 2-6 cm broad, convex becoming plane, often subumbonate; surface a glutinous pellicle, extremely viscid when wet becoming polished when dry, translucent striate; color dark umber brown (ISCC 59) becoming brownish gray at maturity (ISCC 61); context soft, thin, pallid, taste and odor not distinctive. Lamellae adnate to subdecurrent, thick, subdistant, grayish brown (ISCC 63). Stipe 3-7 cm long, 2-5 mm thick, mostly equal, smooth, covered with gluten when wet, polished when dry, concolorous with pileus; context soft, hollow at maturity.

Microscopic Structures: Spores 7-9.5 x 4.5-6 μm , short-elliptical, smooth, inamyloid. Basidia 26-43 x 7-8 μm , clavate, slender, mostly 4-spored, occasionally 2-spored in the same gill; sterigmata up to 6 μm long. Pleurocystidia and cheilocystidia absent. Gill trama subparallel. Cuticle an ixotrichodermium 130-175 μm deep, the hyphae 1-4.5 μm broad, erect and tangled, with irregular bulges and protuberances, not forming a palisade. Pileal trama radial and slightly interwoven, the hyphae pallid yellowish to yellow-brown in KOH, rather inflated, 3.5-14 μm broad; subhymenial hyphae near base abruptly smaller, colorless, and interwoven; laticifers frequent, branched, 1-6 μm broad. Stipe surface an ixotrichodermium similar to that of the pileus, about 200 μm thick. Clamp connections rare on the cuticular hyphae, apparently absent from the hyphae of the gill trama, pileal trama, and stipe surface.

Habit and Habitat: "Gregarious to scattered on humus and soil, in coniferous and mixed woods, in swamps, . . ." (Hesler & Smith p. 221, 1963).

Material Studied: ACAD 8631, Boularderie, Cape Breton Co., 12 Sept. 1962.

Remarks: *Hygrophorus unguinosus* var. *unguinosus* is a rare species in Nova Scotia, distinguished by the blackish to gray, viscid pileus and stipe, the slender stature, and the scarcity of clamp connections.

Hesler and Smith (1963) mentioned a distinct hypodermium. Perhaps this refers to the abruptly colorless smaller subhymenial hyphae found at the base of the pileal trama. If there is a hypodermium near the cuticle, distinguished by a different color, such a color difference was not apparent on rehydration of ACAD 8631 in KOH.

Subsection PUNICEI Fayod
Ann. Sci. Nat. Ser. 7(9): 309. 1889.

Pileus viscid; stipe dry; lamellar trama parallel.

Type species: *H. puniceus* (Fr.) Fr.

Series CONICI (Fayod) Hes. & Sm.

N. Amer. Spec. of *Hygrophorus*, p. 108. 1963.

Pileus sharply to bluntly conic.

Type species: *H. conicus* (Fr.) Fr.

42. *Hygrophorus conicus* (Fr.) Fr. var. *conicus*

Epicr. Myc., p. 331. 1838.

Agaricus conicus Fr., Syst. Myc. 1: 103. 1821.

Hygrocybe conica (Fr.) Kummer, Führ. in Pilzk., p. 111. 1871.

Hydrocybe conica (Fr.) Karsten, Bidr. Finl. Nat. Folk 32: 236. 1879.

Godfrinia conica (Fr.) Maire, Bull. Soc. Mycol. Fr. 18 (Suppl.): 117. 1902.

Hygrocybe pseudoconica Lange, Dansk. Bot. Ark. 4: 24. 1923.

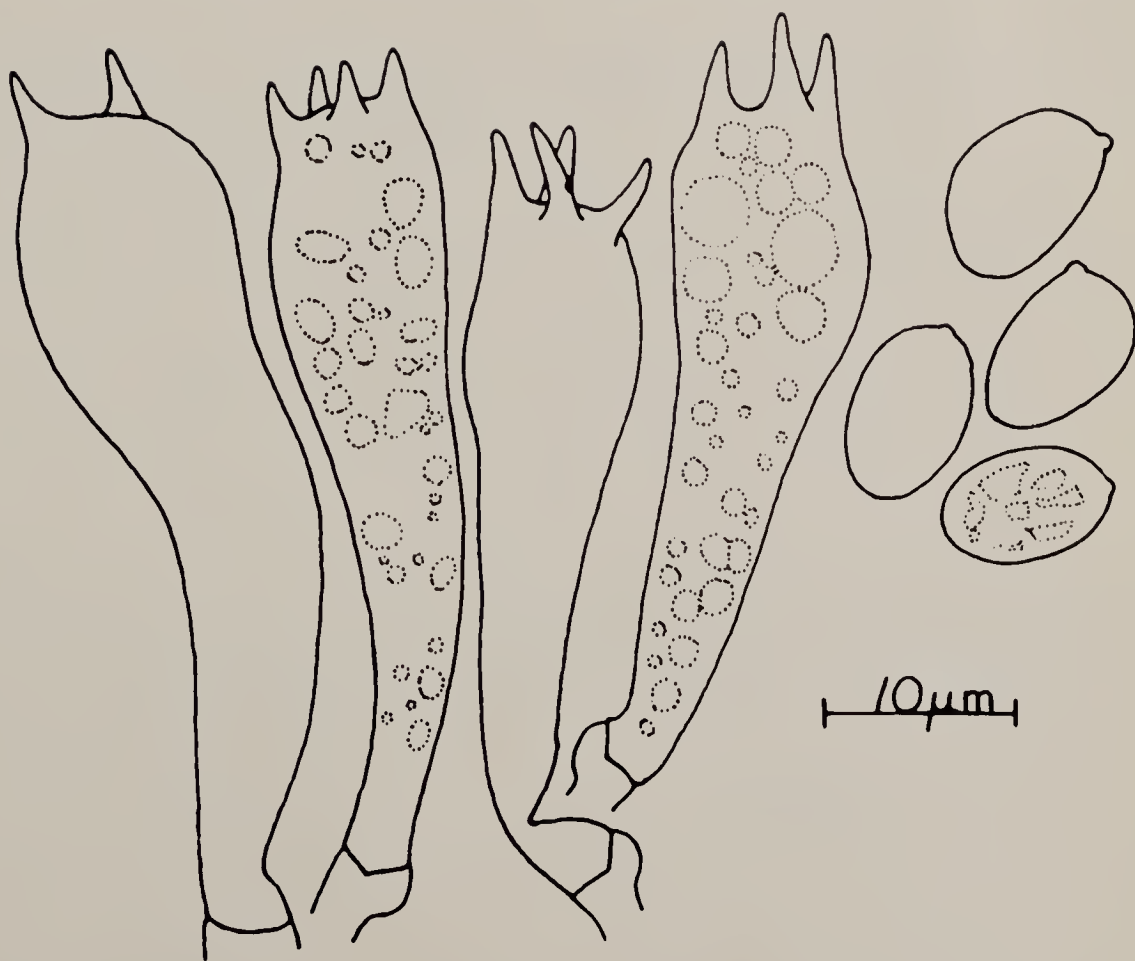
Figs 90, 91.

Basidiocarp: Pileus 0.5-4 cm broad, acutely to broadly conic, becoming obtuse, clasping the stipe at first, slightly viscid when fresh, soon resinous to dry and silky-fibrillose, lobster red (9E8) (ISCC 36) to paprika red (8B8) (ISCC 35) when young, fading in streaks to brick red (7D7) (ISCC 43) or drab orange, usually darker on disc, slowly staining gray to black with age or injury, drying dusky red to black; context thin (up to 5 mm on disc), usually hollow on disc, pale yellow to whitish, or hygrophanous and concolorous with the surface, bruising gray to black, fragile;

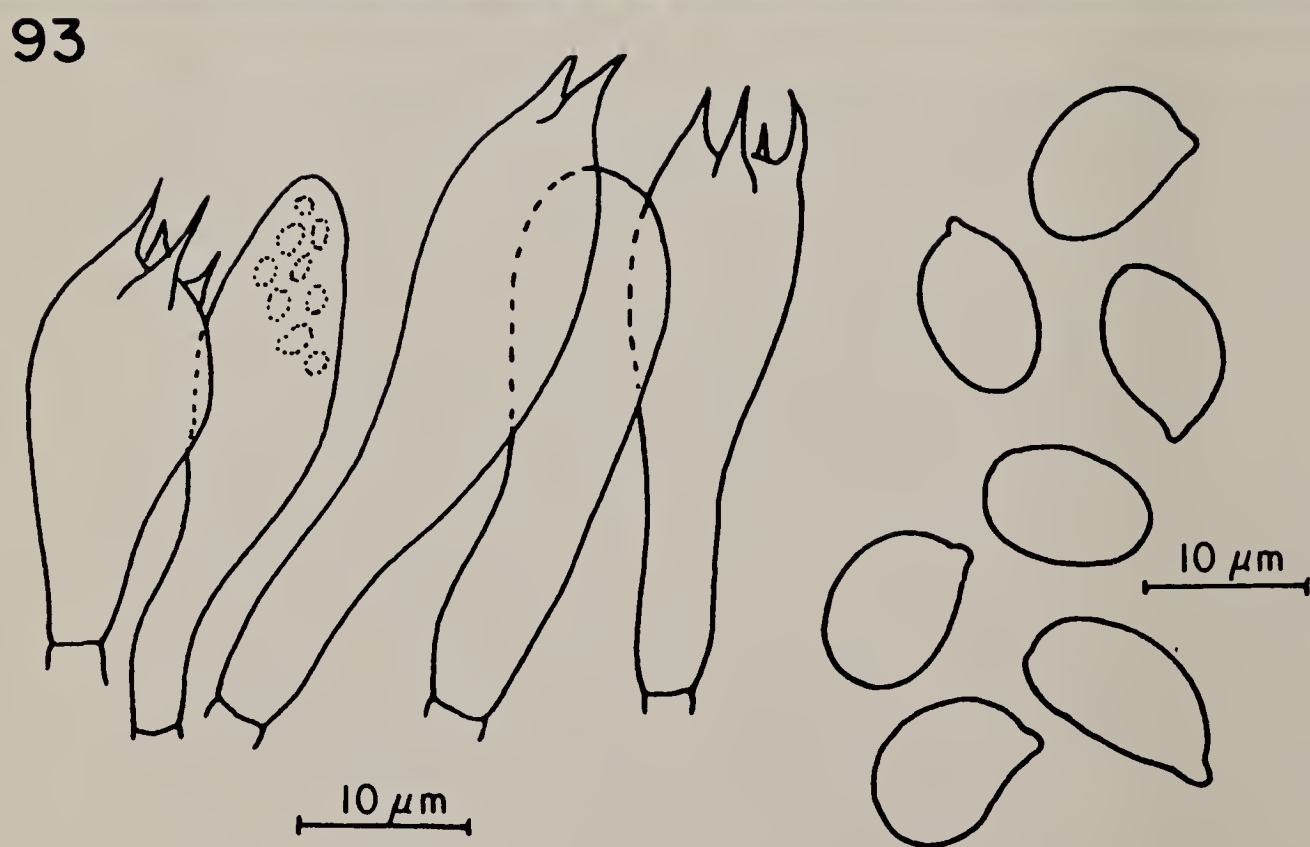
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Figs 90, 91. *H. conicus* var. *conicus*. Fig 90. ACAD 12125, X 1.0. Fig 91. ACAD 12125, basidia and spores.



Figs 92, 93. *H. conicus* var. *atosanguineus*. Fig 92. ACAD 10375, X .65; reproduced by permission of the National Research Council of Canada from the *Canadian Journal of Botany*, 52, pp. 1243-1247, 1974. Fig 93. ACAD 10375, basidia, basidioles, and spores.

odor absent; taste not distinctive or faintly reminiscent of hydrogen peroxide. Lamellae adnexed to nearly free, tangerine (6B8) (ISCC 50) or Persian orange (6A7) (ISCC 50) on faces, paling to yellowish on edges, blackening when injured, subdistant, thick, edges even to eroded. Stipe 2-7 cm long, 4-7 mm thick at apex, at times concolorous with the pileus but usually more yellow, paling to white at base, pallid yellow within, bruising gray to black in all parts, dry, longitudinally striate, equal, usually subcompressed and twisted, easily splitting, hollow.

Microscopic Structures: Spores 8-10 x 5-7 μm , short-elliptical, some approaching oblong, smooth, inamyloid. Basidia 27-46 x 9-12.5 μm , narrowly clavate, relatively short, mostly 4-spored, less frequently 2- and 3-spored in the same gill, the sterigmata stout, up to 5 μm long. Pleurocystidia and cheilocystidia absent. Gill trama parallel, scarcely interwoven, the cells long (up to 200 μm), broad, and with yellow content; laticifers large, scattered. Cuticle a thin, poorly-organized ixocutis of slightly gelatinous brownish hyphae 3.5-7.5(9.5) μm broad. Pileal trama of radial, subparallel hyphae 8.5-39 μm broad, yellowish near the cuticle, with scattered laticifers; hypodermium absent. Clamp connections present in cuticle and upper pileal trama; the large hyphae of the pileal and gill tramas considerably overlapped at the septa but lacking true clamps.

Habit and Habitat: Scattered to gregarious, terrestrial in woods or burned-over forest.

Material Studied: ACAD 12125, Kejimikujik Lake, Annapolis Co., 28 June 1968.

Remarks: *Hygrophorus conicus* is characterized by its reddish, conic pileus and striate stipe which blacken with age or injury. In Nova Scotia, this species is unlikely to be confused with anything but *H. ruber*, which does not blacken and has a viscid, non-striate stipe when fresh. *H. conicus* is actually more common than it would seem from the single collection cited above, and is ubiquitous in temperate North America.

The prevailing number of spores per basidium and, consequently, the spore size varies greatly within the species (Hesler and Smith 1963). Lange (1940) reported only 2-spored basidia for typical *H. conicus*.

43. *Hygrophorus conicus* (Fr.) Fr.

Epicr. Myc., p. 331. 1838.

var. *atrosanguineus* Grund & Harrison

Can. J. Bot. 52: 1243-1244. 1974.

Figs 92, 93.

Basidiocarp: Pileus 1.5-7.0 cm broad, obtusely conic becoming subconic with arched margins at maturity; surface dry, appressed silky-fibrillose, slightly viscid when wet; margins first entire becoming deeply incised, lobed and rimose; dark strawberry red (10D8) (ISCC 13) to violet brown (10E8) (ISCC 16), becoming black when handled or bruised, soon blackening after picking; context thin, concolorous with the pileal surface; odor strongly aromatic, taste not distinctive. Lamellae adnexed; color mustard yellow (3B6) (ISCC 87) to grayish orange (6B6) (ISCC 53) in young specimens, becoming olivaceous ochre (4C7) (ISCC 88) at maturity, blackening upon bruising. Stipe 4.5-10 cm long, 3-10 mm thick, equal, twisted, fragile, and splitting longitudinally; surface subglabrous to minutely fibrillose, dry to moist, not viscid; color reddish orange (7B7) (ISCC 37) to mustard yellow (3B6) (ISCC 87) above, pallid at base; context yellow or concolorous with surface, fibrous, bruising black, hollow.

Microscopic Structures: Spores 8-10 x 5-6.5 μm , smooth, subellipsoid to ellipsoid, some pale yellow, others light brown in Melzer's reagent. Basidia 30-40 x 8-12 (13) μm , normally 4-spored, rarely 2-spored, clavate. Pleurocystidia and cheilocystidia absent. Lamellar trama of parallel hyphae 7-15 μm thick; laticifers present. Pileal surface an epicutis (dried material not rehydrating well in 3% KOH). Clamp connections present on hyphae of cuticle and lamellar trama.

Habit and Habitat: Singly in needle duff in Hemlock woods.

Material Studied: ACAD 10375, ravine 3 km east of Gaspereau, Kings Co., N.S. 24 July 1972.

Remarks: This rare variety has been collected once. The deep blood red pileus that turns black upon handling is striking and characteristic. It differs from *H. conicus* var *conicus* in the darker red pileus and strongly aromatic odor.

Series PUNICEI

Pileus viscid, not conic; stipe dry; lamellar trama parallel.

44. *Hygrophorus flavescens* (Kauff.) Sm. & Hes.

Lloydia 5:60. 1942.

Hygrophorus puniceus var. *flavescens* Kauff., Mich. Acad. Sci. Rep. 8: 34. 1906.

Hygrocybe flavescens (Kauff.) Singer, Lilloa 22: 154. 1951.

Figs 94, 95.

Basidiocarp: Pileus (0.6)1-5 cm broad, bluntly conic or hemispheric young, becoming broadly convex and then plane with a flat to pronounced umbo, or else slightly depressed, the margin persistently decurved, glutinous to viscid when fresh, drying dull satiny, margin faintly striate moist, copper red (7C8) (ISCC 37), brownish orange (6C8) (ISCC 54), tangerine (6B8) (ISCC 50) or dark orange (6A8) (ISCC 48) when young, soon fading on expansion to cadmium orange (5A8) (ISCC 66) or dark golden yellow (5B8) (ISCC 69), finally Chinese yellow (4B7) (ISCC 84), buttercup yellow (4A7) (ISCC 82), or genet (3A7) (ISCC 83), usually retaining orange hues on disc and margin; context thin and often hollow on disc (up to 2 mm thick), membranous over gills, pale yellow to yellow-orange, darker towards pellicle, or hygrophanous and wholly concolorous with the surface, brittle; odor and taste not distinctive. Lamellae adnexed to deeply emarginate, sometimes uncinat, in age seceding and occasionally appearing free, pale yellow-orange becoming yellow toward the edges, or uniformly buttercup yellow (4A7) (ISCC 82) to cream (4A3) (ISCC 89), pale yellow (2A3) (ISCC 104) in age, close to subdistant, 2-6(9) mm broad, edges even or eroded. Stipe (1.3)2-6.5 cm long, 2-10 mm thick at apex, concolorous with the pileus or paler, darkest over the middle, gradually pallid yellow to white at base, at times unilaterally splashed with darker orange or yellow-orange, pale yellow and hygrophanous within, glabrous and satiny, dry, becoming resinous after handling, narrowed above

94



95



Figs 94, 95. *H. flavesceus*. Fig 94. ACAD 12138, X 1.0. Fig 95, ACAD 12103, basidia and spores.



97



Figs 96, 97. *H. puniceus*. Fig 96. ACAD 12246, X 1.0. Fig 97. ACAD 12193, basidia and spores.

when young, later equal or slightly tapered downwards, at times subcompressed with a median longitudinal sulcus, easily splitting, at first stuffed, becoming hollow.

Macroscopic Structures: Spores (6)7-9.5(10.5) x (3.5)4.5-6 μm , short-elliptical or oblong-elliptical at maturity, occasionally broader at apicular end, smooth, inamyloid. Basidia 28-50 x 7-9.5 μm , clavate, slender to rather stout, mostly 4-spored, frequently 2- and 3-spored in the same gill, the sterigmata slender, up to 7 μm long. Pleurocystidia and cheilocystidia absent. Gill trama of parallel or subparallel hyphae 3-18 μm broad, the mediostrate yellow, laticifers scattered. Cuticle an ixotrichodermium 60-300 μm deep, the hyphae gelatinized, more or less erect but some radial and interwoven, 1-6 μm broad, mostly about 2.5-3.5 μm , arising from a dense tangle of yellow hyphae transitional to the context. Pileal trama hyphae radial and subparallel, periclinal over the hymenium, yellowish near the cuticle, 5-15 μm broad; laticifers scattered throughout. Clamp connections frequent in the subhymenium and cuticle, scattered to rare in the gill trama mediostrate and the pileal trama.

Habit and Habitat: Scattered, gregarious, or subcespitose on damp soil in coniferous, mixed, or deciduous woods. Common.

Material Studied: ACAD 12103, ravine, Agriculture Experimental Station, Kenville, Kings Co., 27 Sept. 1967; ACAD 12126, Harrington Woods, Kings Co., 8 July 1968; ACAD 12129, Arlington, Kings Co., 4 July 1968; ACAD 12135, Shell Lake, Kings Co., 8 July 1968; ACAD 12136, Harrington Woods, Kings Co., 8 July 1968; ACAD 12138, 12139, Aldersville, Lunenburg Co., 10 July 1968; ACAD 12249, 12251, Moose River, Pictou Co., 14 Oct. 1968.

Remarks: *Hygrophorus flavescens* has frequently been confused with *H. chlorophanus* in Series *Psittacini*, because the stipe of the former tends to feel sticky after handling. However, sections of fresh material show no gelatinous hyphae on the stipe of *H. flavescens*. Two collections of *H. chlorophanus* from Nova Scotia, Wehmeyer 515 and 515a (Smith and Wehmeyer 1936) are now thought to be *H. flavescens* (A.H. Smith, in litt.).

The elongate, parallel hyphae of the pileal and lamellar tramas are intermediate between the *H. conicus* and *H. coccineus* types. This, plus the bluntly conic pileus of young sporocarps, indicates that *H. flavescens* may be related to Series *Conici*, or even transitional to that group. Because of the variable shape of the pileus this species may be keyed in both the Series *Punicei* and *Conici*.

Hygrophorus marchii is macroscopically similar to *H. flavescens* except for its red to orange color. Hesler and Smith (1963) suggested a close relationship between the two, but we find that *H. marchii* does not display the *H. conicus* type of hyphal arrangement to the same degree as *H. flavescens*, and has a definite ixocutis instead of an ixotrichodermium.

45. *Hygrophorus puniceus* (Fr.) Fr.

Epicr. Myc., p. 331. 1838.

Agaricus puniceus Fr., Syst. Myc. 1: 104. 1821.

Hygrocybe punicea (Fr.) Kummer, Führ. in Pilzk., p. 112. 1871.

Hydrocybe punicea (Fr.) P. Karst., Bidr. Finl. Nat. Folk 32: 235. 1879.

Figs 96, 97.

Basidiocarp: Pileus 1.5-5 cm broad, bluntly conic-convex at first, becoming obtuse to planoconvex and subumbonate, margin persistently decurved, viscid, soon drying dull to glossy, appressed fibrillose, deep blood red when moist, fading in radial streaks to copper red (7C8) (ISCC 37), brownish orange (6C8) (ISCC 54), or tangerine

(6B8) (ISCC 50); context thick (4.5-7 mm) on disc, abruptly thinning toward margin, butter yellow (4A5) (ISCC 86) to champagne (4B4) (ISCC 90) often tinged sordid pale orange, soft, fragile; odor and taste not distinctive. Lamellae adnate young, soon deeply emarginate or adnexed, usually with a decurrent tooth, pallid yellow when young, later amber yellow (4B6) (ISCC 87) or corn (4B5) (ISCC 71), often flushed with pale orange, occasionally entirely rosy or grayish orange (6B5) (ISCC 53), glaucous, broad at maturity (up to 10 mm), subdistant, thick, brittle, edges even or eroded. Stipe 2-7 cm long, 5.5-9.5 mm thick at apex, sienna (6D7) (ISCC 54) above, gradually yellowish downwards, soon yellow overall and streaked with orange, whitish at base, light yellow within, dry, more or less fibrillose-striate, narrowed above when young, later subequal or tapering downwards, occasionally flexuous, stuffed at first, soon hollow.

Microscopic Structures: Spores (8)8.5-12.5(13.5) x 4-6 μm , elliptical in dorsal aspect, at times long-obovate or subconstricted in the middle, smooth, inamyloid. Basidia 44-61 x 7-8.5 μm , long-clavate, slender, 4-spored, rarely 2-spored in the same gill, the sterigmata up to 6 μm long. Pleurocystidia and cheilocystidia absent. Gill trama of subparallel hyphae 2.5-18.5 μm broad; laticifers frequent, 2.3-6 μm broad. Cuticle an ixocutis (45) 250-480 μm deep, of radial, interwoven, more or less appressed gelatinous hyphae 2.3-3.5 μm broad. Pileal trama radial, slightly interwoven, the hyphae yellowish, inflated, 3.5-21 μm broad. Clamp connections present in the cuticle, gill trama and pileal trama.

Habit and Habitat: Solitary to gregarious on soil or leaf mold in mixed woods. Frequent.

Material Studied: ACAD 12193, Perry Road, Yarmouth Co., 22 Sept. 1968; ACAD 12246, Moose River, Pictou Co., 14 Oct. 1968.

Remarks: It is important to check for a gelatinous cuticle in both fresh and dried material. Often, a specimen will have all the macroscopic and microscopic attributes of *H. puniceus* except for a viscid pellicle. Such specimens belong in the *H. puniceus*-*H. coccineus* complex. (See *Complexes*, p.).

Hygrophorus coccineus resembles *H. puniceus* in habitat, stature, and color, but the pileus of the former species is moist to dry and the lamellae are persistently adnate. It also occurs much less commonly than *H. puniceus*. Spore size and/or color of the stipe base have been used to distinguish the two (Kauffman 1918; Krieger, 1935; Wakefield and Dennis 1950), but these features are variable and intergrading, or only slightly different at best. Spore shape is a more reliable feature, being elliptical in *H. coccineus* and oblong-elliptical or approaching subfusiform in *H. puniceus*.

Hygrophorus marchii is also close to *H. puniceus*, but is a smaller, more slender species with only a very thin gelatinous pellicle and differently-shaped spores. (See *H. marchii* for a more detailed comparison).

Hesler and Smith (1963) noted that spore size in *H. puniceus* varies considerably within 4-spored forms, and that the variability is augmented by the existence of 1-, 2-, and 3-spored forms.

46. *Hygrophorus marchii* Bres.

Icon. Myc. 7: 343. 1928.

Hygrocybe marchii (Bres.) Singer, Lilloa 22: 153. 1951.

Figs 98, 99.

Basidiocarp: Pileus 1-2 cm broad, planoconvex or the disc depressed, viscid but soon dry, glabrous, margin translucent-striate moist, scarlet at first, unevenly fading

red-orange to yellow; context thin (up to 1 mm on disc), yellow, fragile; odor and taste not distinctive. Lamellae adnate and uncinata, yellow-orange to orange, subdistant, thin, edges even. Stipe 3-4 cm long, 2.5-3.5 mm thick at apex, yellow-orange above, elsewhere concolorous with the pileus, yellow within, glabrous, nonviscid, equal, terete, hollow.

Microscopic Structures: Spores (6.5)7-11(12) x 4-6(7.5) μm , ellipsoidal to oblong, at times slightly constricted in middle, or pear-shaped, smooth, inamyloid. Basidia 29-55 x 6.5-10 μm , clavate to long-clavate, generally rather short, 2- and 4-spored, rarely 1- and 3-spored in the same gill; sterigmata slender, up to 7 μm long in 4-spored basidia, to 9.5 μm long in 2-spored basidia. Brachybasidioles rare and localized, 41-47 x 11-15 μm , sphaeropedunculate. Pleurocystidia and cheilocystidia absent. Gill trama of subparallel hyphae 3-18.5 μm broad, with scattered laticifers 1-2.5 μm broad. Cuticle a thin ixocutis 13-86 μm deep, of radial, repent, gelatinous hyphae 1-3 μm broad. Pileal trama of radial and slightly interwoven hyphae 2-22 μm broad, brownish near the cuticle as revived in KOH; hypodermium absent. Clamp connections present in the gill trama, cuticle and pileal trama.

Habit and Habitat: Scattered in mixed woods. Rare.

Material Studied: ACAD 12255, Moose River, Pictou Co., 14 Oct. 1968.

Remarks: Except for the red color and the pellicle being an ixocutis instead of an ixotrichodermium, *H. marchii* as treated here is almost identical with *H. flavescens*. Perhaps it should be regarded as a color variant of that species, as our specimens are more slender than those illustrated by Bresadola (1928) and Hesler and Smith (1963). However, stature is an arbitrary and variable feature, and further collecting may yield stouter, more typical specimens.

Hygrophorus marchii is rather difficult to separate from *H. puniceus*. Hesler and Smith (1963) used depth of cuticle in their keys, contrasting the well-developed (at least 50 μm thick) pellicle of *H. puniceus* with the thin (10-25 μm) pellicle of *H. marchii*. In our experience, the *H. marchii* pellicle may be only 13 μm thick near the margin, but nearly 90 μm thick on the depressed, moist disc where the gluten accumulates or is better developed. However, even 90 μm is too thin for a typical *H. puniceus* pellicle. We find the spores are a good distinguishing feature, being broader for their length and more frequently oblong-constricted in *H. marchii*. The combination of stature, pellicle thickness, and spore shape seems to be a satisfactory means of correct identification.

Subsection HYGROCYBE

Pileus and stipe moist or dry, not viscid; lamellar trama parallel.

Series MARGINATI ser. nov.

Pileus conicus.

Species typica: *H. marginatus* Pk.

47. *Hygrophorus marginatus* Pk. var. *marginatus*

N.Y. State Mus. Ann. Rep. 28: 50. 1876.

Hydrocybe marginata (Pk.) Murr. N. Am. Flora 9: 378. 1916.

Tricholoma marginatum (Pk.) Singer, Mycologia 35: 154. 1943.

Humidicutis marginata (Pk.) Singer, Sydowia 12: 225. 1958.

Figs 100, 101.

Basidiocarp: Pileus (0.2)0.5-4 cm broad, hemispheric to bluntly conic young, later broadly conic, obtuse, or convex, at times plane and umbonate with uplifted margin, glabrous, hygrophanous, slightly resinous when moist, margin at times obscurely striate moist, reddish orange (7A8) (ISCC 34) when young and moist, soon fading to cadmium orange (5A8) (ISCC 66), melon yellow (5A6) (ISCC 70), buttercup yellow (4A7) (ISCC 82) or a pale, diffuse orange, the disc and margin usually fading last; context thin (to 2 mm on disc), usually hollow on disc, fragile, whitish to pale yellow, hygrophanous, becoming concolorous with the surface towards the cuticle; taste and odor not distinctive. Lamellae ascending-adnate, becoming adnexed or emarginate in age, often uncinat, reddish orange (7A8) (ISCC 34) to dark orange (6A8) (ISCC 48), fading more slowly than the pileus and the color persisting at least on the edges, thick, subdistant, becoming moderately broad (1-6 mm), brittle, edges even or eroded. Stipe (0.7) 1-4.5 cm long, 1.5-8 mm thick at apex, at first dark orange (6A8) (ISCC 48) above, paling downwards to whitish, soon uniformly melon yellow (5A6) (ISCC 70) to butter yellow (4A5) (ISCC 86), pallid yellow to whitish within, glabrous, not viscid, very fragile, hollow, subequal, at times slightly compressed, often flexuous.

Microscopic Structures: Spores (6.5)7-11.5 x 4.5-6(7) μm , shape variable, subglobose to short-elliptical, at times attenuated to apiculus, smooth, inamyloid. Basidia-22-46 x 8-9.5 μm , clavate, relatively short and stubby, much narrowed or bifurcate at base, 1-, 2-, and 4-spored in varying proportions; basidioles clavate, rarely cylindrical. Pleurocystidia and cheilocystidia absent. Gill trama subparallel, the cells 9.5-11.9 x 5.5-14 μm , slender to inflated, often short and cyst-like, laticifers frequent, branched, 2.3-4.5 μm broad. Cuticle a thin epicutis of radial, nongelatinous hyphae, generally repent but frequently detached or reflexed, 2.5-8 μm broad, merging with the context hyphae. Pileal trama of radial, subparallel hyphae, similar to gill trama hyphae, with scattered, branched laticifers 3-6 μm broad; hypodermium absent. Clamp connections frequent at the bases of the basidia but absent in the gill trama, the cuticle, and the pileal trama.

Habit and Habitat: Gregarious in damp soil, humus, or *Sphagnum*, in mixed or deciduous woods.

Material Studied: ACAD 12149, Aylesford Lake, Kings Co., 30 July 1968; ACAD 12152, Hebb's Cross, Lunenburg Co., 4 Aug. 1968; ACAD 12178, Aylesford Lake, Kings Co., 30 Aug. 1968; ACAD 12183, ravine, Agriculture Experimental Station, Kentville, Kings Co., 10 Sept. 1968.

Remarks: The most distinctive feature of this species is the brilliant orange hymenophore which retains its color after the pileus fades or after the fungus has been dried. Also, the stipe is more fragile than is usual in section *Hygrocybe*, and breaks or splits unless handled very carefully. Since the pileus may be either conic or convex, the fungus may be keyed in both Series *Marginati* and *Coccinei*.

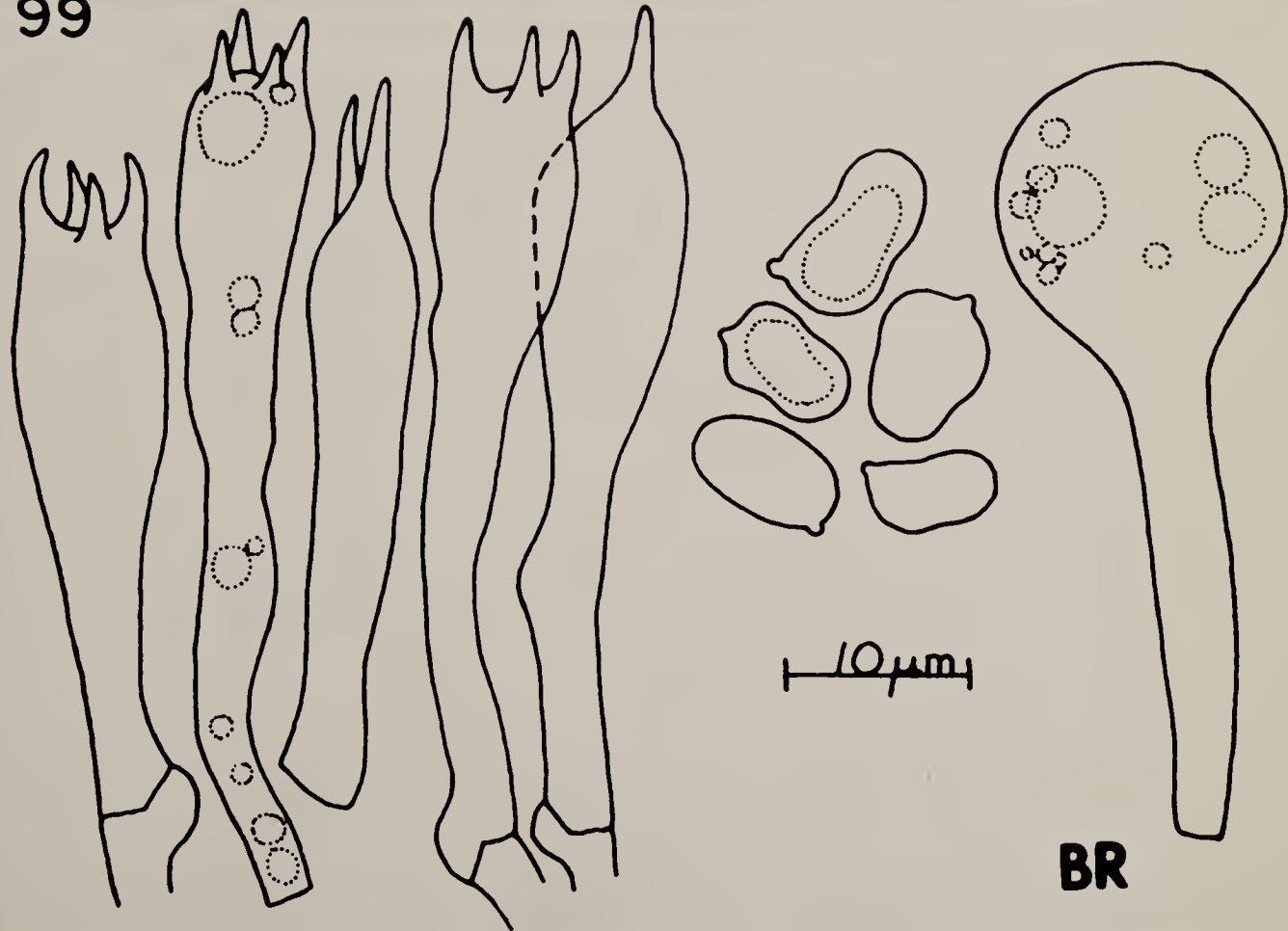
Spore size varies considerably within the species, depending on the prevailing number of spores per basidium. For example, in ACAD 12149, the basidia are typically 4-spored and occasionally 2-spored with spores 6.5-8.5(9.5) μm long. In ACAD 12152, the basidia are usually 1- or 2-spored and rarely 4-spored, with spores 8-11.5 μm long. Thus, spore size is not a reliable diagnostic feature. However, except

Figs 98, 99. *H. marchii*. Fig 98. Smith 63713, X 1.25; from *North American Species of Hygrophorus* by L.R. Hesler and A.H. Smith, (c) 1963 by the University of Tennessee Press, Knoxville; reprinted by permission of the University of Tennessee Press. Fig 99. ACAD 12255, basidia, spores, and brachybasidiole (BR); redrawn by permission of the National Research Council of Canada from the *Canadian Journal of Botany*, 48, pp. 403-411, 1970.

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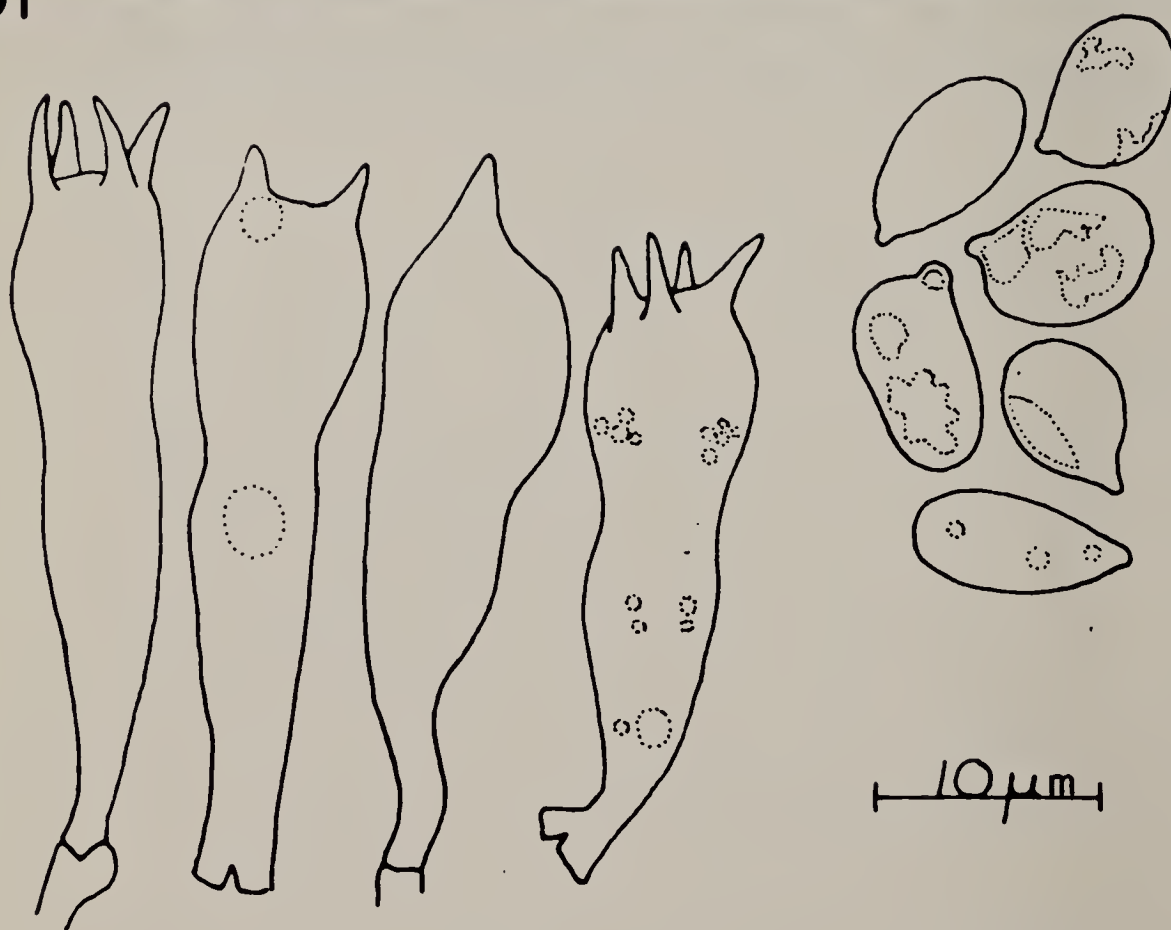


99





101



Figs 100, 101. *H. marginatus* var. *marginatus*. Fig 100. Smith 63764, X 1.25. Fig 101. ACAD 12149, basidia and spores.

for the number of sterigmata, basidium morphology seems consistent and distinctive.

Clamp connections, regarded by most authors as absent, occur frequently at the bases of the basidia. Absence of clamps was a diagnostic feature of *Humidicutis*, erected by Singer (1958) to accommodate this and several other species.

48. ***H. marginatus* Pk.**

N.Y. State Mus. Rep. 28: 50. 1878.

var concolor Sm.

Pap. Mich. Acad. Sci., Arts, and Lett. 38: 59. 1953.

Fig 102.

Basidiocarp: Pileus 1.5-3 cm broad, conic, glabrous, moist and hygrophanous to subviscid when wet, striatulate at margin, orange-yellow (4A8) (ISCC 82) becoming butter yellow (4A5) (ISCC 86) in age; context brittle, thin, concolorous; odor and taste lacking. Lamellae adnate, distant, melon yellow (5A6) (ISCC 70). Stipe 3-5 cm long, 4-7 mm thick, equal, Chinese yellow (4B7) (ISCC 84), glabrous; context brittle, concolorous, becoming hollow.

Microscopic Structures: Spores 8-10 x 6-7 μm , subellipsoid to ovoid, thin-walled. Basidia 30-40 x 7-9 μm , subcylindric to long-clavate; some basidioles cystidioid. Pleurocystidia and cheilocystidia absent. Lamellar trama parallel centrally, tending to become interwoven beneath hymenium. Pileal surface undifferentiated, of thin, interwoven, non-gelatinous hyphae. Clamp connections not observed.

Habit and Habitat: Scattered at edges of swamps.

Material Studied: ACAD 12437, Aylesford Lake, Kings Co., 18 Sept. 1977.

Remarks: This beautiful *Hygrophorus* was locally abundant in the vicinity of Aylesford Lake in autumn of 1977, but had not been collected previously in the province. The lamellae are paler than in the type variety, wherein they are persistently deep orange. Its affiliation with the type variety is evident in the conic pileus and fragile stipe, the relatively stubby basidia, and the structure of the lamellar trama.

Series HYGROCYBE

Pileus convex to depressed, fibrillose-scurfy to squamulose on the disc at maturity, not viscid; stipe dry; lamellar trama parallel.

49. ***Hygrophorus cantharellus* (Schw.) Fr.**

Epicr. Myc., p. 329. 1838.

Agaricus cantharellus Schw., Schr. Nat. Ges. Leipzig 1: 88. 1822.

Camarophyllus cantharellus (Schw.) Murr., N. Am. Flora 9: 388. 1916.

Hydrocybe cantharellus (Schw.) Murr., Mycologia 3: 196. 1911.

Figs 103, 104.

Basidiocarp: Pileus 0.5-3 cm broad, convex young, soon convex-umbilicate, at times depressed and the margin recurved at maturity; moist to dry, becoming fibrillose-scurfy to minutely squamulose on or around disc, the detached fibrils concolorous with or paler than the pileus, elsewhere glabrous to appressed fibrillose, margin at times translucent-striate, brownish red (10C8) (ISCC 13) when young and fresh,

fading slowly and unevenly to tangerine (6B8) (ISCC 50), light orange, and finally yellow-orange; context thin (1-1.5 mm on disc), pale yellow to yellow-orange, darker under the cuticle, at times whitish on disc, fragile; odor and taste not distinctive. Lamellae decurrent, pale yellow, sometimes flushed orange, subdistant, thin, narrow to broad (1-5 mm), brittle, edges even or eroded. Stipe (1.3) 3-7.5 cm long, 2-8 mm thick at apex, concolorous with the pileus or paler, sometimes fading more slowly and then darker than the pileus, base pallid orange to yellow, or whitish from a coating of mycelium, glabrous, not viscid, satiny to nacreous, rarely pruinose, equal or slightly enlarged above, terete or subcompressed; context stuffed to hollow, pale yellow to yellow-orange, or else concolorous with exterior with a pale yellow to whitish pith.

Microscopic Structures: Spores 7-11(15.5) x 4.5-7.5(9) μm , short-elliptical, smooth, inamyloid. Basidia 34-68 x (4.5)7.5-13 μm , long-clavate, mostly 4-spored, rarely 1-, 2-, or 3-spored in the same gill, the sterigmata large, stout, 6-10.5(18.5) μm long. Pleurocystidia and cheilocystidia absent. Gill trama subparallel to rather interwoven, the hyphae 3.5-35 μm broad, narrow to inflated, usually yellow within. Cuticle a narrow zone of nongelatinous, colorless to pale brown hyphae, slightly narrower than the context hyphae, radial, repent or reflexed in squamules, the terminal cells cylindrical and sometimes incrustated with amorphous brown matter. Pileal trama radial and slightly interwoven, the hyphae 4-38 μm broad, slender to inflated, yellow-brown near the cuticle, yellow to colorless elsewhere; hypodermium absent. Clamp connections present in the cuticle, gill trama, and pileal trama.

Habit and Habitat: Solitary, gregarious, or subcespitose on soil or leaf mold in mixed woods; occasionally among grass or mosses on sandy soil. Frequent.

Material Studied: ACAD 12124, Aldersville, Lunenburg Co., 26 June 1968; ACAD 12164, Aylesford Lake, Kings Co., 17 Aug. 1968; ACAD 12169, Cape Split, Kings Co., 22 Aug. 1968; ACAD 12256, Moose River, Pictou Co., 14 Oct. 1968.

Remarks: This species differs from *H. miniatus* var. *miniatus* mainly in its usually more slender stature, its decurrent lamellae, and its larger spores. The larger, stouter sterigmata are also characteristic, but this distinction between *H. cantharellus* and *H. miniatus* may not be readily apparent unless material of both species is available for comparison.

Hygrophorus cantharellus is a variable species. Peck (1901; 1907) separated var. *flavipes*, var. *flaviceps*, var. *flava*, and var. *roseus*. The first three are color forms which Hesler and Smith (1963) evidently regarded as variations of the normal fading pattern of the sporophore. Var. *roseus* is a type with a wavy, uplifted margin, such as may occur in old, expanded pilei. Our collections indicate that the general aspect of the fungus depends greatly on weather and habitat; thus, any local *Hygrophorus* with a red to yellow-orange, scurfy, umbilicate cap and pale yellow, decurrent lamellae should be suspected of being *H. cantharellus*, and the identification should be confirmed by measurements of spores and basidia.

Murrill (1916) placed *H. cantharellus* in the genus *Camarophyllus*, presumably because of the occasionally interwoven lamellar trama. However, the tramal hyphae are broad and inflated compared with the narrow, uniform hyphae typical of lamellar trama in Section *Camarophylloopsis*. Moreover, *H. cantharellus* has all the macroscopic attributes of Series *Hygrocybe*, and is too close to *H. miniatus* to be segregated in a different section.

Kauffman (1918) discussed this species as *H. miniatus* var. *cantharellus* Schw., and stated that it intergrades with *H. miniatus* (See also *Complexes*, p.).

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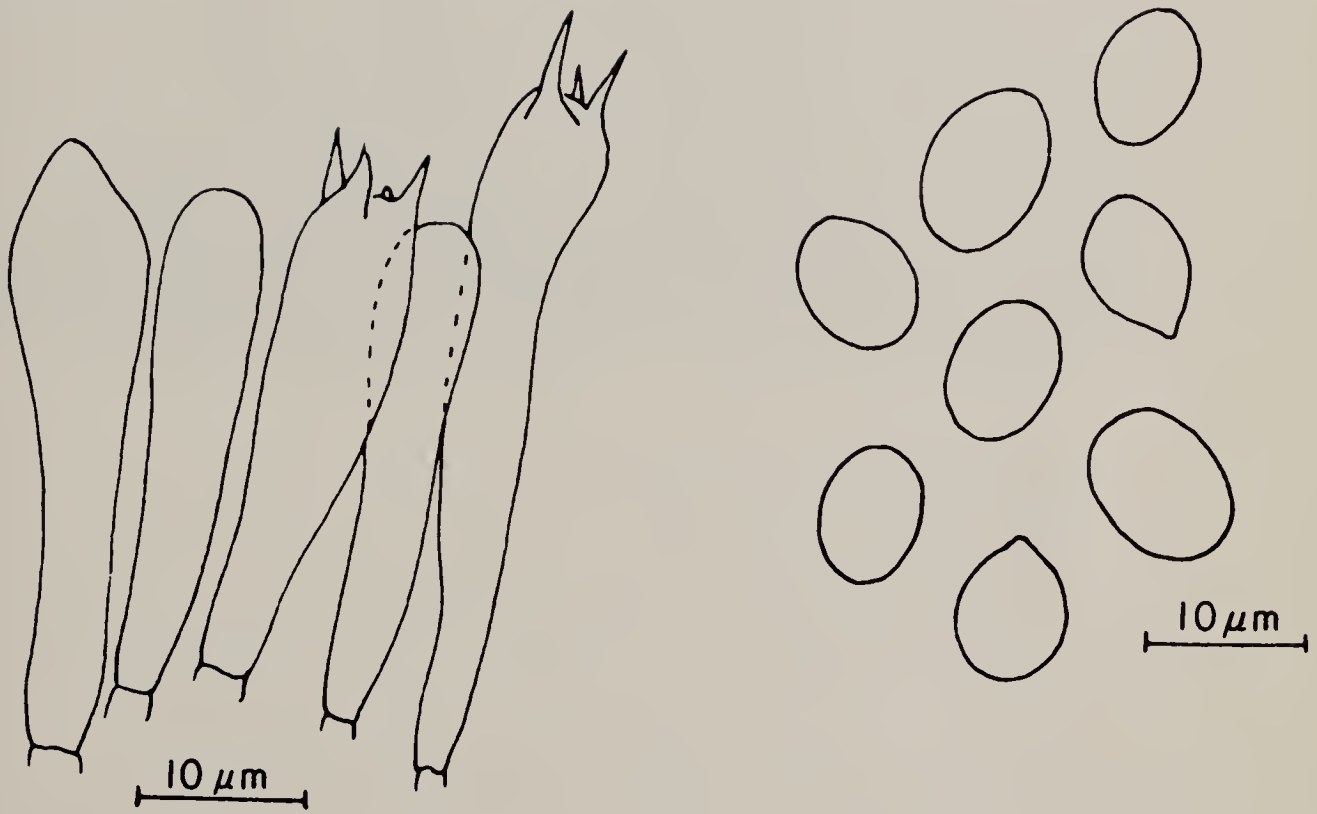
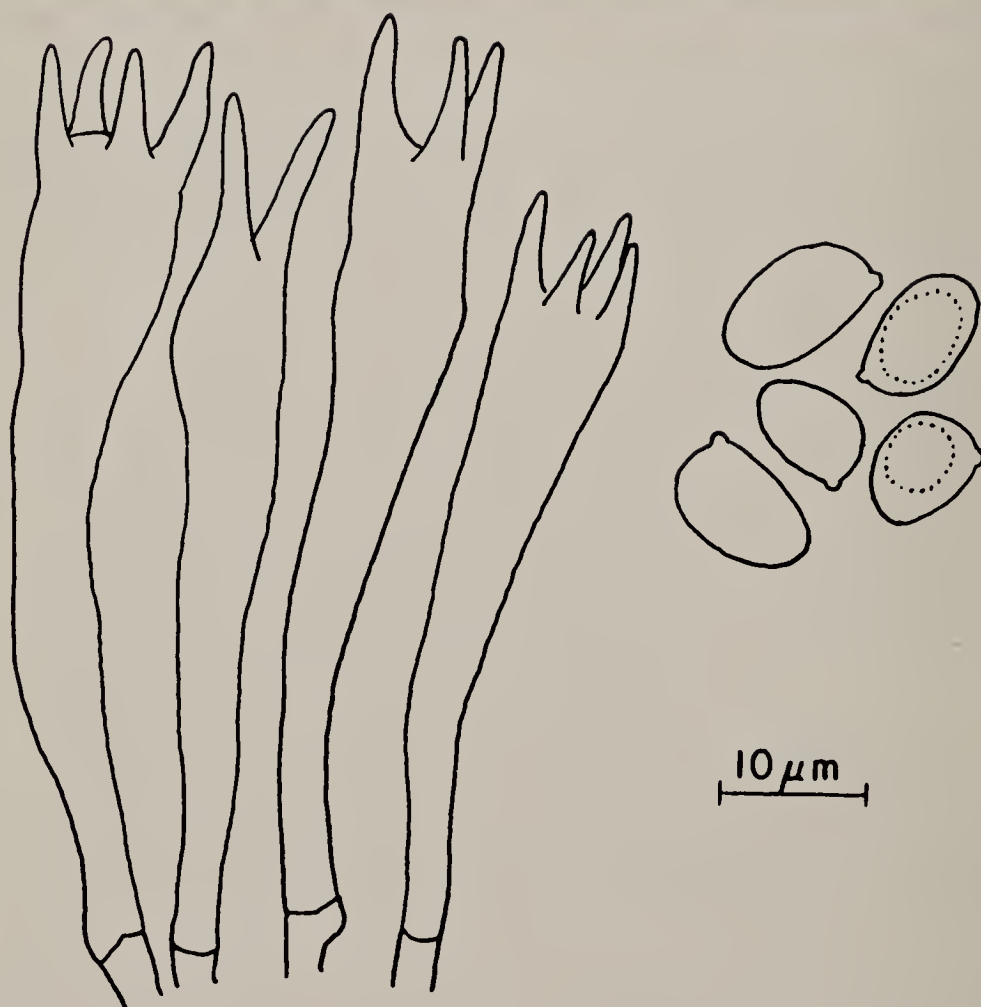


Fig 102. *H. marginatus* var. *concolor*. ACAD 12437, basidioles, basidia, and spores.

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Figs 103, 104. *H. cantharellus*. Fig 103. Smith 63554, X 1.25. Fig 104. ACAD 12164, basidia and spores.

50. **Hygrophorus miniatus (Fr.) Fr. var. miniatus**

Epicr. Myc., p. 330. 1838.

Agaricus miniatus Fr., Syst. Myc. 1: 105. 1821.*Hygrocybe miniata* (Fr.) Kummer, Führ. in Pilzk., p. 112. 1871.*Hygrophorus congelatus* Pk., N.Y. State Cab. Ann. Rep. 23: 114. 1873.*Hygrophorus flammans* Schroeter, Die Pilze Schlesiens 31: 528. 1889.*Hygrophorus miniatus* var. *congelatus* Pk., N.Y. State Mus. Bull. 116: 61. 1907.*Hydrocybe constans* Murr., Mycologia 4: 208. 1912.*Hygrophorus constans* Murr., Mycologia 4: 217. 1912.*Hydrocybe flammea* (Scop.) Murr., N. Am. Flora 9: 381. 1916.*Hygrophorus miniatus* Fr. var. *typicus* Sm. & Hes., Lloydia 5: 28. 1942.

Figs 105, 106.

Basidiocarp: Pileus 0.5-2.5 cm broad, at first convex or the disc flattened, margin incurved, later planoconvex to depressed, at times umbilicate, becoming fibrillose-scurfy or squamulose at least on disc, margin sometimes faintly translucent-striate or crenate; paprika red (8B8) (ISCC 35) to reddish orange (7A8) (ISCC 34) when young and moist, and then appearing glabrous to appressed fibrillose, fading to orange or yellow or mixtures of these; context thin (0.5-2.5 mm on disc) hygrophanous and concolorous with surface, or else pale yellow to yellow-orange, darker beneath cuticle, fragile; odor and taste not distinctive, or else odor earthy. Lamellae broadly adnate to subdecurrent, usually becoming adnexed, at times deeply emarginate or uncinuate, light yellow, often flushed pale orange, narrow when young, becoming broad (1-6.5 mm), subdistant to rather close, thick, brittle, edges even or eroded. Stipe 2-6 cm long, 1.5-5 mm thick at apex, brownish orange (6C8) (ISCC 54) or tangerine (6B8) (ISCC 50) above, becoming yellow downwards, or else orange below and paler above, fading overall to maize yellow (4A6) (ISCC 83), whitish at base, pale yellow or yellow-orange within, glabrous, not viscid, nacreous when moist, equal or narrowed downwards, terete or subcompressed above, stuffed, becoming hollow.

Microscopic Structures: Spores (6)7-10(11.5) x 4-6(7.5) μm , short-elliptical, oblong-elliptical or ovate, smooth, inamyloid. Basidia 29-45 x 6-8 μm , clavate, slender, mostly 4-spored but rare to occasional 1-, 2-, and 3-spored basidia occurring in the same gill, the sterigmata slender, up to 7.5 μm long. Pleurocystidia and cheilocystidia absent. Gill trama subparallel with a yellowish mediostrate, the cells 42-231 x 11-16 μm , with slender hyphae 1.5-4.5 μm broad interspersed. Cuticle a narrow zone of compact, radial, yellow hyphae, nongelatinous, narrower than the context hyphae, repent, or reflexed to form squamules, the terminal cells cylindrical or tapered, or rarely clavate. Pileal trama radial and subparallel, colorless to pale yellow, the cells 32-172 x 17-30 μm , with slender hyphae 2.5-5.5 μm broad interspersed; hypodermium absent. Clamp connections small and inconspicuous, present in the cuticle and the gill trama, infrequent in the pileal trama.

Habit and Habitat: Scattered to gregarious and subcespitose, usually among *Sphagnum* or other mosses; in bogs or swales; often among ferns (*Osmunda* spp) under conifers. Common.

Material Studied: ACAD 12160, Hebb's Cross, Lunenburg Co., 9 Aug. 1968; ACAD 12167, Hebb's Cross, Lunenburg Co., 19 Aug. 1968; ACAD 12187, 12188, Gaspereau Valley, Kings Co., 16 Sept. 1968.

Remarks: *Hygrophorus miniatus* var. *miniatus* is a common and variable species recognized by its red to orange, scurfy pileus and its adnate to adnexed gills. Its close relative *H. cantharellus* is similar but more slender, and has strongly decurrent gills. For additional comments on the 2 species, see the *H. miniatus*-*H. cantharellus* complex. (*Complexes*, p. 11).

The name *miniatus* has been applied to another species of *Hygrophorus*, which will cause confusion unless descriptions accompany the records. Murrill (1916) described *Hydrocybe miniata* (Scop.) Murr. as having a viscid pileus, and listed *Hygrophorus miniatus* Schroet., among others, as a synonym. Because of the viscid pileus, neither of these epithets can be considered synonymous with *H. miniatus* as treated here. (See also *H. coccineus*).

Series COCCINEI (Fayod) Hes. & Sm.

N. Am. Spec. of *Hygrophorus*, p. 171. 1963.

Pileus convex to depressed, glabrous or appressed fibrillose, not viscid; stipe dry; lamellar trama parallel.

Type species: *H. coccineus* (Fr.) Fr.

51. *Hygrophorus nitiosus* Blytt

Norges Hymenomycetes. Vidensk. Selsk. Skr. I. Math. Naturv. Kl. 1904.
No. 6. p. 88. 1905.

Hygrocybe ingrata Jensen & Moeller, Fungi of the Faeröes, p. 136. 1945.

Hygrocybe nitiosa (Blytt) Moser apud Gams, Kleine Kryptogamenfl. von Mitteleuropa, p. 37. 1953.

Figs 107, 108.

Basidiocarp: Pileus 1-2 cm broad, hemispheric, expanding slightly, dry, obscurely fibrillose-scaly or with some of the fibrils recurved near the disc; teak brown (6F5) (ISCC 78), paling to tan (6E6) (ISCC 58) on margin; context 1-2 mm thick on disc, membranous over gills, brownish-white, slowly staining light pinkish brown when injured odor; nitrous; taste acidulous, then of hydrogen peroxide. Lamellae deeply emarginate, seceding, whitish, slowly bruising pinkish brown to dark brown, subdistant, broad (2-4 mm), thick and brittle. Stipe 3.5-5 cm long, 4-7 mm thick at apex, dingy brownish, slowly bruising dark brown, staining light brownish within, drying dark brown, dry, glabrous, equal or slightly expanded above, usually subcompressed or with a median longitudinal sulcus, easily splitting, stuffed to hollow.

Microscopic Structures: Spores 7.5-10 x 4-5.5 μ m, ellipsoidal, smooth, inamyloid. Basidia 32-45 x 7-10.5 μ m, clavate, stout at first, becoming slender, mostly 4-spored, with 2- and 3-spored basidia frequent in the same gill, the sterigmata slender, to 7 μ m long. Hymenial cystidia absent. Gill trama subparallel. Cuticle of dry, brownish hyphae, repent or reflexed in squamules, the terminal elements cystidioid. Pileal trama radial and subparallel; hypodermium not seen. Clamp connections on hyphae of cuticle and gill trama.

Habit and Habitat: Scattered in grassy clearing. Rare.

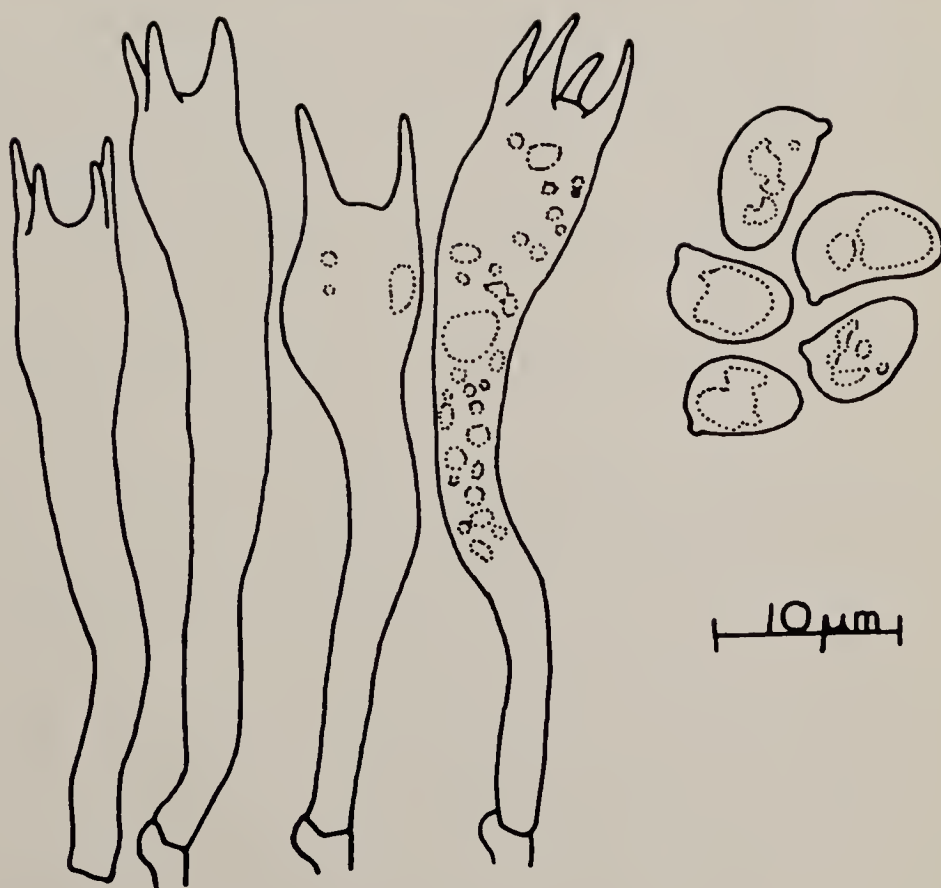
Material Studied: ACAD 12137: Aylesford, Kings Co., 7 July 1968.

Remarks: *Hygrophorus nitiosus* is readily distinguished by its brown, coarsely fibrillose pileus, its nitrous odor, and the slow color change of its flesh to brownish when injured. It stands between *H. nitratus* Fr., which has a nitrous odor but does not stain on injury, and *H. ovinus* (Fr.) Fr., that lacks a nitrous odor but bruises. Neither of the latter two species has yet been found in Nova Scotia.

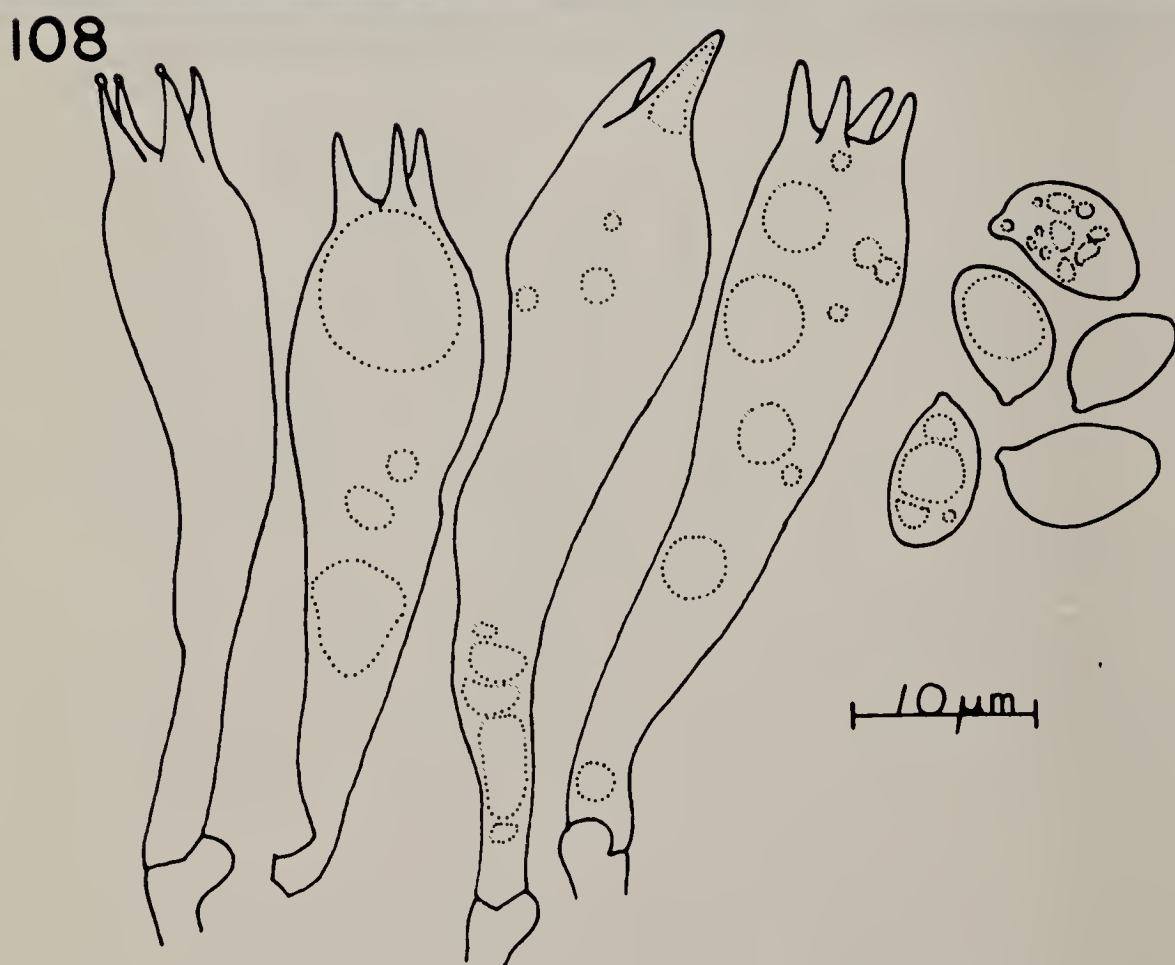
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Figs 105, 106. *H. miniatus* var. *miniatus*. Fig 105. ACAD 12160, X 1.25. Fig 106. ACAD 12160, basidia and spores.



Figs 107, 108. *H. nitiosus*. Fig 107. ACAD 12137, X 1.5. Fig 108. ACAD 12137, basidia and spores; redrawn by permission of the National Research Council of Canada from the *Canadian Journal of Botany*, 48, pp. 403-411, 1970.

Because the surface fibrils sometimes recurve near the disc, *H. nitiosus* also may be keyed in Series *Hygrocybe*. However, the pileus disc does not become truly squamulose or fibrillose-scurfy as in *H. nitratus* and other species of Series *Hygrocybe*.

Note that *H. conicus*, which bruises gray to black, may also taste like hydrogen peroxide.

52. *Hygrophorus coccineus* (Fr.) Fr. sensu Ricken

Die Blätterpilze, Band 1, p. 23. 1915.

Agaricus coccineus Fr., Syst. Myc. 1: 105. 1821.

Hygrophorus coccineus (Fr.) Fr. Epicr. Myc., p. 330. 1838.

Hygrocybe coccinea (Fr.) Kummer, Führ. in Pilzk., p. 112. 1871.

Figs 109, 110.

Basidiocarp: Pileus 1-2.5 cm broad, broadly conic to convex, eventually plane and umbonate with margin uplifted, glabrous, not viscid; strawberry red (10D8) (ISCC 13) when young, fading to orange; context thin (2-3 mm on disc), pale yellow to yellow-orange, or hygrophanous and concolorous with the surface, slowly grayish in FeSO_4 , fragile; odor and taste not distinctive. Lamellae adnate, at times seceding, Pompeian red (9C7) (ISCC 15) to dull peach, paling toward edges to yellow, subdistant, thick, broad (2-4.5 mm), brittle, edges even. Stipe 0.5-4 cm long, 2-6 mm thick at apex, buttercup yellow (4A7) (ISCC 82) splashed with strawberry red (10D8) (ISCC 13), whitish at base from a thin coating of mycelium, maize yellow (4A6) (ISCC 83) within, dry or moist, glabrous, uneven from irregular, shallow indentations, straight or twisted, hollow.

Microscopic Structures: Spores 8-10.5(11) x 4.5-6 μm , ellipsoidal, smooth, inamyloid. Basidia 38-61 x 8-10.5 μm , long-clavate, 4-spored, the sterigmata stout, up to 6 μm long. Pleurocystidia and cheilocystidia absent. Gill trama of subparallel hyphae 4-18.5 μm broad. Cuticle of repent, radial, nongelatinous hyphae 2.3-6 μm broad, little differentiated from the context. Pileal trama of radial, subparallel to slightly interwoven hyphae 5-17.5 μm broad. Clamp connections present on the hyphae of the cuticle, gill trama, and pileal trama.

Habit and Habitat: Gregarious to subcespitose on soil under hemlocks and other conifers. Rare.

Material Studied: ACAD 12100, ravine, Agricultural Experimental Station, Kentville, Kings Co., 23 Sept. 1967.

Remarks: This species resembles *H. puniceus* in color, stature, habitat and spore size. The major feature distinguishing the two is the absence of a viscid cuticle in *H. coccineus*, supported by arbitrary and variable characteristics such as smaller size, typically adnate gills, and slightly smaller spores. However, we found that specimens with nearly all the macroscopic attributes of *H. puniceus* frequently lacked the viscid cuticle, yet could not be *H. coccineus* because of robust stature, and basidia and overly large spores typical of the 1-, 2-, and 3-spored forms of *H. puniceus*. (see *Complexes*, The *H. puniceus*-*H. coccineus* complex for detailed discussion). Thus, it is important to examine the cuticle and basidia carefully, and consider a combination of macroscopic features before deciding the correct name. Hesler and Smith (1963) noted that *H. puniceus* is a common and variable species, whereas *H. coccineus* is rare.

Of the two earlier collections labelled *H. coccineus* in the E.C. Smith herbarium, Acadia University, ACAD 1595 (Marshalltown, Digby Co., 18 Sept. 1952) has proved

to be one of the *H. puniceus*-*H. coccineus* complex because of the large, oblong-elliptical spores on 1- and 2-spored basidia. The other collection, ACAD 9781 (New Albany, Annapolis Co., 19 Aug. 1966), appears to be *H. miniatus* var. *miniatus* because of its slender stature and the depressed, scurfy pileal disc of the most mature specimen. As no field notes exist for the latter collection, and as we have seen too little of *H. coccineus* in Nova Scotia to be familiar with its general appearance here, we hesitate to exclude this collection completely from consideration.

Murrill (1916) relegated *H. coccineus* Fr. to synonymy with *Hydrocybe miniata* (Scop.) Murr. (not a synonym of *H. miniatus* var. *miniatus* as treated in this work). As he described the pileus as viscid, his nomenclature is questionable with respect to both species. Hence, we adopt the concept of *H. coccineus* established by Ricken (1915).

53. *Hygrophorus macrosporus* sp. nov.

Figs 111, 112.

Pileus 3 cm latus, convexus, glaber, non viscidus, flavo-aurantiacus, in sulphate ferri tarde fuscens; caro tenuis, fragilis, flavida, odore et sapore miti. Lamellae liberae, flavae, aurantiacis pallidis suffusae, subdistantes et latae (6 mm). Stipes 7 cm longus, 7 mm crassus, glaber vel leviter striatus, pileo concolorus; caro flavida, cava. Sporae 12.5-16.5(18) x 6.5-9.5(11) μ m, ellipticae. Basidia 37-56 x 12-15 μ m, clavata, pro parte maxima duobus sterigmatibus, raro uno sterigmate.

Holotypus ACAD 12099, in sylvis coniferis (Tsuga) prope Kentville, comitato Kings, Nova Scotia lectus, in herbario Universitatis Acadensis conservatus.

Basidiocarp: Pileus 3 cm broad, convex, glabrous to silky, not viscid, yellow-orange (ISCC 67), drying dull orange, not bruising, slowly grayish brown in FeSO_4 ; context thin (2 mm) on disc, membranous over lamellae, yellow, unchanging, fragile; odor and taste not distinctive. Lamellae free, light yellow flushed with pale orange, subdistant, broad (6 mm), thin, brittle. Stipe 7 cm long, 7 mm thick at apex, concolorous with the pileus, light yellow within, dry, glabrous to faintly longitudinally striate, tapering slightly toward base, subcompressed, hollow.

Microscopic Structures: Spores 12.5-16.5(18) x 6.5-9.5(11) μ m, elliptical to oblong-elliptical, at times almost obovate or reniform, smooth, inamyloid. Basidia 37-56 x 12-15 μ m, clavate, relatively short, at times pedicellate, mostly 2-spored, rarely 1-spored, the sterigmata stout, up to 9 μ m long; basidioles clavate, markedly smaller. Brachybasidioles sporadic, 15-46 x 12-22 μ m, napiform to sphaeropedunculate. Pleurocystidia and cheilocystidia absent. Gill trama parallel, scarcely interwoven, with a dense, darker mediostrate, the hyphae (1.7)3.5-21.5 μ m broad, sparingly septate; laticifers scattered. Cuticle a fairly well-defined epicutis of repent, radial or loosely interwoven, nongelatinous hyphae 2.3-9.5 μ m broad. Pileal trama of radial, parallel hyphae 6-41 μ m broad; laticifers frequent near the cuticle, 1.7-11.5(19) μ m broad, irregular, branched and contorted; hypodermium absent. Clamp connections absent, the hyphae truncated or overlapped at septa.

Habit and habitat: Solitary in hemlock woods.

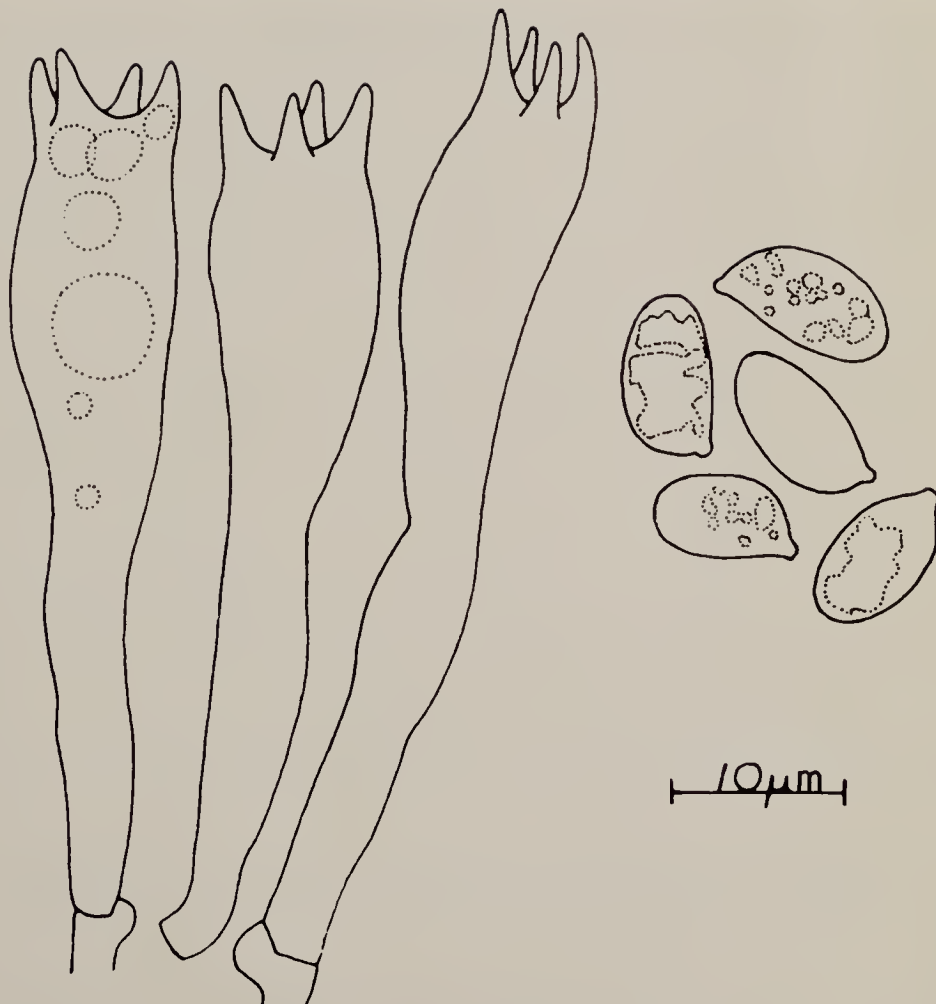
Material Studied: ACAD 12099 (holotype), ravine, Agriculture Experimental Station, Kentville, Kings Co., 18 Sept. 1967.

Remarks: Superficially, *H. macrosporus* resembles *H. flavescens*, but has a dry, more uniformly colored pileus. The large, straight parallel hyphae of the gill and pileal tramas, the broad cuticular hyphae and laticifers, and the faintly striate stipe indicate an affiliation with the conic series. These features plus free lamellae and absence of clamp connections place the species close to *H. cuspidatus* Pk. in Series *Conici*, but *H. macrosporus* is convex and yellow-orange instead of sharply conic

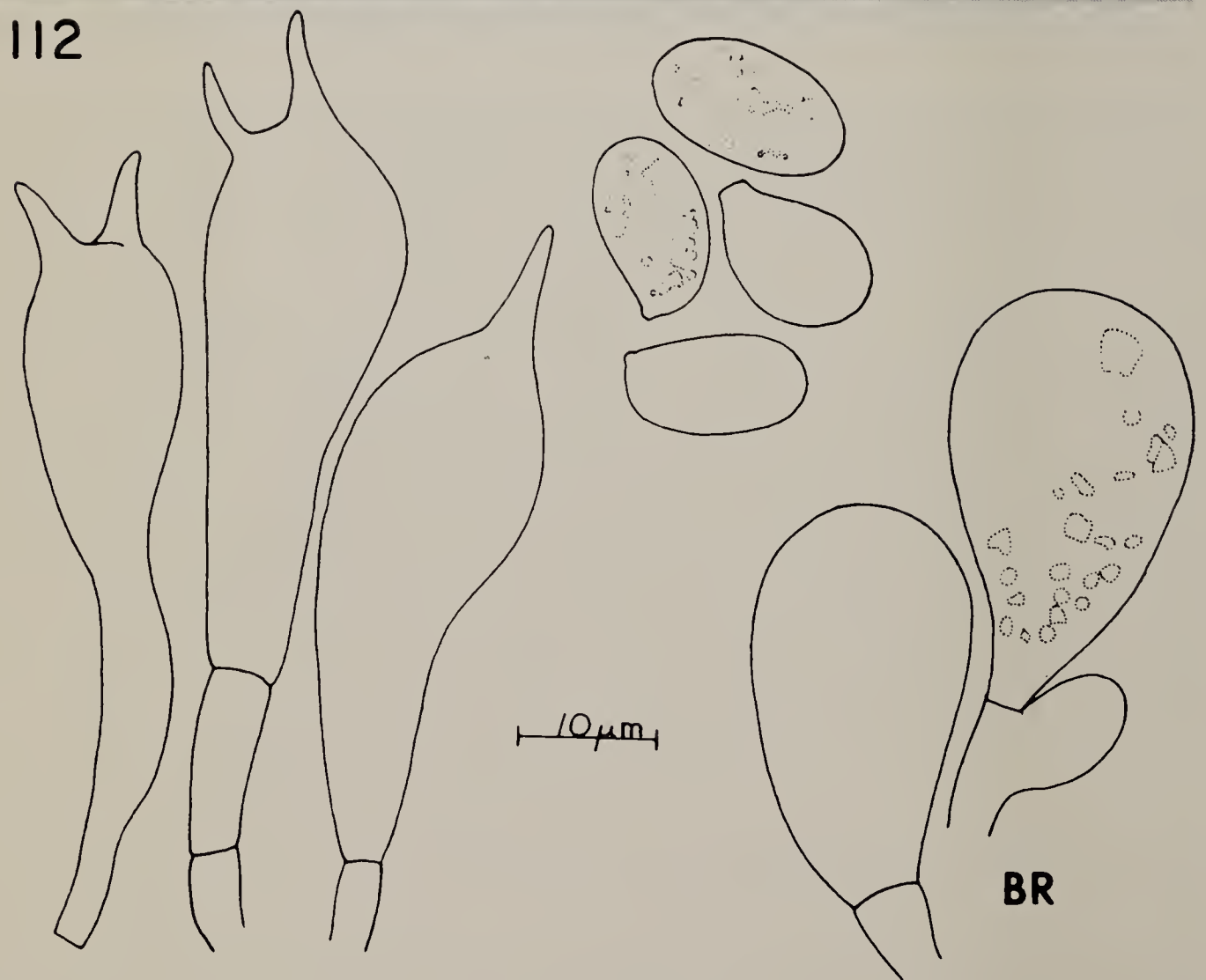
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Figs 109, 110. *H. coccineus*. Fig 109. Smith 64644, X 1.5. Fig 110. ACAD 12100, basidia and spores.



Figs 111, 112, *H. macrosporus*. Fig 111. ACAD 12099, X 1.25. Fig 112. ACAD 12099, basidia, spores, and brachybasidioles (BR).

HYGROPHORUS

and persistently red, and lacks a viscid cuticle even in section. Large spores, also characteristic of *H. cuspidatus* and its relatives, in *H. macrosporus* are undoubtedly caused by a prevalence of 2-spored basidia. There may be a 4-spored or a 2- and 4-spored counterpart, as the number of spores per basidium frequently varies within *Hygrophorus* species.

The uniform yellow color and lack of clamps also suggest a relationship with *H. marginatus* var. *concolor* of Series *Marginati*, especially as we have occasionally observed convex pilei in the typical variety of *H. marginatus*. However, the free lamellae and *conicus* type of lamellar trama amply distinguish *H. macrosporus* from *H. marginatus*. Thus, as the pileus of the single specimen of *H. macrosporus* collected to date is convex and dry, we are assigning this species to Series *Coccinei*.

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INSTRUCTIONS TO AUTHORS

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Manuscripts should be typewritten, double-spaced on white paper 21.5 by 28 cm (8.5 by 11 in) with margins of 4 cm (1.5 in). Underline only material to be set in italics, and use capital letters only when letter or words should appear in capitals in the printed paper. Layout and style should follow that used in this volume. The original copy and one duplicate are required. Each page of the manuscript should be numbered, the first page carrying only the title, authors' names and affiliations, and any necessary footnotes.

Spelling should follow that of **Webster's Third New International Dictionary**, and authors are responsible for consistency in spelling.

Abbreviations, nomenclature, and symbols for units of measurements should follow international recommendations. Metric units, SI units and decimals should be used whenever possible. Use day/month/year sequence for dates. Do not use periods after such abbreviations as "mm, kg, DOE, NRC, etc."

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PROCEEDINGS

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VOL. 29

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La Revue *Proceedings of the Nova Scotian Institute of Science* publie les travaux de l'Institut, des articles originaux et des notes avant trait aux sciences naturelles aux Provinces atlantiques, surtout dans les domaines de la biologie et de la géologie. Les manuscrits peuvent être en anglais ou en français, et seront soumis à l'avis d'experts avant d'être acceptés.

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L'orthographe doit se conformer au **Larousse encyclopédique**. Les auteurs sont responsables de l'uniformité de l'orthographe dans leurs textes.

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Volume 28 (1978) p. 181:

title. (PHAEOPHYTA: SCYTHOSIPHONACEAE)
should read. (PHAEOPHYTA: SCYTOSIPHONACEAE)

THE THIRD A. C. NEISH MEMORIAL LECTURE

INTRODUCTION OF F. R. HAYES

M. L. CAMERON*

First, on behalf of the A.C. Neish Memorial Trust, I wish to thank the Nova Scotian Institute of Science, who co-sponsor these lectures, and who publish them in their *Proceedings*.

A few words on the purposes of this Trust are in order. A.C. Neish was an outstanding Canadian scientist, who devoted his working life to the service of science and of Canada, as a research officer of the National Research Council of Canada, and finally as director of the Atlantic Regional Laboratory of the National Research Council. His achievements as a scientist were recognized by his fellow scientists in the honors he received during his lifetime, not the least being the highest award British scientists can bestow, a fellowship in the Royal Society of London, and since then by his friends and colleagues who have established this Trust in his memory.

It is the aim of the Trust to bring to audiences in the regions where Arthur Neish lived and worked scientists of international eminence who can acquaint us with their work and thoughts in science. The first 2 lecturers to the Trust chose to discuss their opinions of the impact of science on society, presenting a not altogether cheerful picture. The third lecturer, Dr. F.R. Hayes, has chosen to discuss the possible scientific bases for social behavior.

Ronald Hayes is so well known to Canadian audiences as to need no introduction. Beginning some half-century ago, as Professor of Zoology and later as Vice-President of Dalhousie University, he made significant contributions to the freshwater ecology and fisheries of Nova Scotia, and to university education in the sciences, and was instrumental to the founding of the Institute of Oceanography. Later as Chairman of the Fisheries Research Board of Canada, his expertise and wise counsel were extended to the nation.

It is a unique pleasure to his friends and colleagues, that on his retiring from the Fisheries Research Board, he and Dr. Pelluet chose to return to Halifax, not to retirement, but to a renewal of academic activity, which has produced the book, *The Chaining of Prometheus*, a perceptive study of the interaction of government and science in Canada, and has led to the foundation of the Institute for Environmental Studies at Dalhousie University.

So, it is from a long life of study and experience that Dr. Hayes speaks to us about: "The evolutionary basis for religious belief: Marx's takeover bid for Darwinian sociobiology."

* Chairman, A.C. Neish Memorial Trust

THE EVOLUTIONARY BASIS FOR RELIGIOUS BELIEF: MARX'S TAKEOVER BID FOR DARWINIAN SOCIOBIOLOGY

F. R. HAYES*

E. O. Wilson's evidence is examined, that altruism and religion are explicable as offering genetic and evolutionary advantage. Reasons are given for regarding Wilson's critics in the so-called Harvard controversy, as a Marxist religious group rather than as science-based biologists. The implications of the controversy on scientific belief, religious belief, and on truth are discussed.

A general problem which I am going to talk towards and talk around this evening is one of the oldest in biology and one of the first to be introduced to beginning students. It is called nature versus nurture, that is the extent to which the hereditary characters of an organism can be eliminated or altered by manipulation of the environment. We are all performing such manipulations all the time, with activities which range from adding fertilizers and weed killers to our lawns, to training efforts with children and adults. The particular example which we shall examine is the social behavior of man, particularly in the religious area and in its relation to recent research in biology.

Our discussion is concerned with recent expansions which have taken place in the scope of several familiar ideas. One of them is about the term religion which, among materialist groups aggressively opposed to the supernatural, tends to become confused with political and social movements. Another is in the field of human evolution, evidence for which was originally developed from an examination of structures, but whose study today is concerned as well with behavior. A third area of vigorous contemporary research is in the study of animal and human social groups, whose survival through natural selection may be aided by inherited unit characters—Mendel's word, today we say genes - genes of altruism and, among humans, of religion.

May I begin with a word about the levels of approval which are enjoyed today by religion and science. The two stand in unexpected and reciprocal relations, where the predicted directions of their growth patterns are not borne out by events. On the one hand formal religion, which has been on the decline ever since the Renaissance, has failed to regress towards its final extinction, which was supposed to accompany the wider spread of the Enlightenment. It is evidently more deeply rooted in our behavior patterns than had been thought. On the other side science has, during the centuries, been coming up towards its final triumph as the universal remedy for life. But instead of the expected adulation, it is increasingly embattled by groups of critics whose attacks are many-sided and include (Graham 1978):

damage to the environment, such as destruction of the ozone layer by escape into the upper atmosphere of chemicals used in aerosols, or the killing of children by spruce budworm sprays

fears about the outcome of "genetic engineering", perhaps through the accidental production of a pathogenic organism immune to antibiotics, or even eventually tinkering with the gene pool of humanity

*Department of Biology and Institute for Resource and Environmental Studies, Dalhousie University, Halifax, N.S.

all sorts of doubts about nuclear research and development, ranging from over-costly proposals such as the Chalk River project to build a super-reactor called INC (rejected), to fears about our inability to find safe storage places for radioactive waste, or concern about the costs of power plants in both energy and money compared with their expected returns

“subversive knowledge” which is seen as conflicting with the theories of ruling authorities, and ranges all the way from Galileo to the subject of the present report.

When theory and fact are at odds it is worthwhile to enquire why, and my purpose is to look at one facet of the general dilemma.

Godless Religions

In his Massey lectures with the title “Nostalgia for the Absolute”, George Steiner talks about the effects of the decline in influence of formal religions and churches on Western society. Various causes for the decrease have been cited, including the rise of scientific rationalism since the Renaissance; scepticism about superstition and the supernatural; Darwinism; modern technology. But really the causes are secondary—the point is that in the West the life-springs of theology have dried up.

When men are deprived of the beliefs which have governed their lives, and their father’s lives, they are left with a deep-seated nostalgia for the absolute. That nostalgia—profound in most of us—was brought on by the decline of the ancient and magnificent architecture of religious certainty. We hunger for total explanation; we are starving for guaranteed prophecy. The response to our hunger has been to create substitute theologies or, as Steiner prefers to call them, mythologies. To qualify for the status of mythology, that is to attract widespread belief, a doctrine or body of thought must meet the criterion of totality; it must affirm that the analysis which it puts forward of your life and mine, is a total analysis. To become a religion, a mythology must claim to draw a complete picture of “man in the world” and invite people to offer themselves totally to a Founder, say Marx. Secondly, religious movements have usually begun with a remarkable event from which the entire system springs (publication of *Das Kapital*). Soon some of the disciples break away into rival groups or sub-mythologies or heresies; the orthodox in the movement will hate such heretics more violently than if they were heathen unbelievers, recognizing that heretics are the real threat. As its third criterion a true mythology will develop its own language, its own characteristic idiom, its own images, metaphors and dramatic scenarios, to be found for example in the Marxist analysis of capitalism.

Steiner goes on to suggest that our political and philosophic history of the past 150 years represents a series of attempts to fill the central emptiness left by the erosion of theology. The “Little Green Men” as he calls them, encompass one of the most discouraging and inadequate of the series of post religious mythologies. They flourish especially on our continent and include such beliefs as Astrology and Horoscopes, Flying Saucers, Clairvoyants, the Hidden Atlantis, saffron-robed votaries of Hare Krishna, Chariots of the Gods, and all the rest of the spooks.

Another post religious theology, whose description I shall not pursue, is called by Steiner “Voyages into the Interior”, and deals with the variants of the science, or pseudo-science, of Freudian psychoanalysis. The classical theories of Freud, we are told, are already receding into history, they are not clinically verifiable, and his techniques are falling into disuse.

Of all the substitute theologies, Marxism is the one that has had the widest acceptance and greatest influence. For millions it satisfies the criteria for a mythology. From the believer it asks for total commitment of conscience and person. In return it

offers a complete explanation of man's biological and social reality and a hope for society's future redemption. It had an identifiable founder with his original small group of followers. Soon it acquired heretics like Trotsky and Mao who have been in ferocious conflict with the orthodox. To bring about the promise of Marxism—the withering away of the state and the classless society without poverty, oppression, or war—for all this generations of idealists have sacrificed their lives and have visited untold suffering on dissenters and heretics. In the academic world Darwinism has for a long time been an heretical view, and today the chief dissenter-in-residence is Edward O. Wilson.

Like other materialistic faiths, Marxism was from its outset savagely anti-religious with its Godless world and denial of an after life. Nonetheless its claims on the believer have always been religious in strategy and effect and have shown at decisive points the marks of a theological past. Now as we shall see later, it is central to Wilson's thesis that religion is a genetic character with a survival advantage for man; accordingly one may anticipate the gradual acceptance of the supernatural by Marxism.

The direction towards re-entry is evident in these quotations (cited from Wilson, the second one abbreviated).

From Mao Tse-tung: We must persevere and work increasingly, and we too will touch God's heart. Our God is none other than the Chinese people.

From a Lenin disciple and spokesman: A real Communist becomes in a way a miracle man and will readily cast from his mind ideas in which he has believed for years, and will submerge his personality in the collectivity of the Party.

On Sociobiology

Our discussion deals with a dispute which has arisen about whether the behavior and social structure of mankind is more correctly to be interpreted by the theories of Darwin or of Marx. It may be asked where religion comes in, since both of these gentlemen were atheists. But if, as evidence suggests, the tendency to religious belief is among our genetic characters, subject to the laws of heredity, then it may be argued that Marxism itself has become a theology. In many countries Marxism is part of a state-religious-complex which, as we shall see, is one of the oldest systems known to human civilizations. The Marxists then, may be taken to occupy the position in the modern dispute that was filled by the Bishops in the Darwinian debates of a century ago.

The central figure in the present debate is Edward O. Wilson, a Harvard biologist, and the leadership of opposition to his views is also Harvard led, which is perhaps an appropriate status for a great university to occupy. Wilson has written a trilogy that unfolded, like Mendel's laws or Darwin's thesis, out of his own field of research. The first volume was on insect societies, which led him in turn to apply to vertebrates the approach to population biology that had worked so well in explaining the social systems of insects. In the final chapter of the second book he argued that his approach could profitably be extended to the social sciences to explain the behavior of man. "This suggestion" as Wilson remarks in understatement, "created an unusual amount of interest and controversy". In truth it evoked a renewal of the furor that had greeted Darwin's research findings a century earlier. The debate has now led Wilson to amplify his views in a third volume "On Human Nature" in which he develops, among other topics, his conclusion that religious practices can be mapped onto the two dimensions of genetic advantage and evolutionary change.

But, as he warns, even if there is a material basis for religion, its comparative study will be difficult to interpret, because human mythologies are unique and not derived in any direct way from animal behavior.

In the modern extension of Darwinism called Sociobiology, behavior is studied as well as structure. Darwin's famous dictum "Man still bears in his bodily frame the indelible stamp of his lowly origin" is considered to take in his mental operations as well as his flesh and bones. It is held that behavior should be pursued and its findings weighed as the best means we have of tracing the evolutionary history of the mind. Sociobiology carries with it the implication that much of man's behavior towards his fellows may be a product of evolution. But how much? A key scientific issue concerns the extent to which human social behavior is genetically determined (see Caplan 1978).

Our nearest relatives, structurally, are the Old World monkeys and the great apes and with them we share such behavioral patterns as these among others:

Our intimate social groups are about 10 to 100 adults, not 2 as in most birds or thousands as often with fishes and insects. The early hunter-gatherers lived as extended family bands of 25 to 100 who assembled when searching for food. Their customs included territoriality and aggression, and their ranges were similar in size to those of wolf packs and somewhat larger than those of gorilla bands. Studies of the human groups have included, among others, Eskimos, Australian aborigines, and North American Indians.

Males are larger than females and the larger among males compete more successfully for females. There is mild polygamy, so that the average male consorts with up to three females.

The young are moulded by a long period of social training with the mother, then with older children.

Social play is strongly developed, featuring mock aggression, sex practice and role practice.

Altruism and food-sharing with close relatives has been observed among chimpanzees.

There are parallels in styles of facial expression and in grimaces of fear, smiles, and laughter.

Added to these shared characters, our own species is distinct in ways that can only be explained as a result of our unique set of some 250,000 genes which bring about the composite human behavior patterns. From a list of 67 cited by Wilson, here are a few random samples: athletics, adornment, cooking, education, food taboos, hairstyles, language, law, medicine, propitiation of supernatural beings, religious rituals.

The heart of Darwinian evolutionary theory, as applied by Wilson, is that during that past 5 million years or so, genes determining many of the specifics of human behavior spread through the population. Changes occurred under the influence of natural selection, random drift, etc., just as with the genes that determined the

characteristics of human anatomy. Individuals who displayed the traits now considered distinctly human stood a better chance of having their genes represented in the next generation. When the process began man's progenitors were not yet in the genus *Homo*, much less the species *Homo sapiens*. Genetic fitness for human behavior offered improved chances for personal and reproductive survival for the individual, as well as for his or her close relatives who shared the same genes.

Taboos against incest are among the universals of social behavior which are supported by religious sanctions. In the case of the brother-sister taboo there is an even stronger than cultural enforcement, namely a physical sexual aversion which develops between small children. These taboos confer genetic fitness and a corresponding loss of fitness results from incest. Even a moderate amount of inbreeding results in children who are diminished in stature, in muscular coordination and in academic performance. More than 100 recessive genes have been associated with hereditary diseases. It appears that natural selection has guided human beings into a favorable instinct based on genes.

Biology's Unique Handicap and The New Anti-Darwinism

Our first effort in this discourse was to clarify a certain confusion which exists between religious and secular convictions. We turn now to a peculiarly biological involvement. The history of science has been a search for principles which could bring order to a large body of hitherto discrete facts. Take chemistry for instance: its earliest classification was into 4 elements, earth, air, fire, and water. Gradually knowledge was extended until, about the middle of the last century, Mendeleev unified the subject with his remarkable periodic table, which was so advanced that it was even capable of predicting the properties of still undiscovered elements. During the early years of this century, his table was expanded by the addition of radioactive elements which decayed into other ones. In the '30's another great expansion began with Urey's discovery of heavy hydrogen and the manufacture by the Joliot-Curies of the first of the long series of artificial elements. Throughout all these developments Mendeleev continued to be held in high honor and repute, as researchers developed, modified, and expanded his unifying principle.

The illustration provided by chemistry could be paralleled in other fields; indeed we think of science in general as a disinterested search for truth with no evident ideological base. Biology, like other sciences, has a long history of its search for order. In early times the variety of living creatures was encompassed by two classes, animal and vermin. Refinements to this simplistic explanation of life continued to appear until, just 10 years before Mendeleev, Darwin offered in *The Origin of Species* his great unifying principle of natural selection. But, as we all know, Darwinism turned out to be too dangerous to the interests of churchmen to be left free for objective evaluation. It aroused a protracted storm of controversy which during this century has gradually become less prominent. But quite recently a new flare-up has appeared and a new idea is being pressed by some scientists—call it religious or political or ideological—an idea that in certain aspects of biology, research should be restricted so that unwanted conclusions may not appear. Questions concerned with the inheritance of human behavior, or possible differences in intelligence between sexes or between races are to be regarded as 'off limits', and prudent scientists are warned to stay in an acceptable stream of research if they are to hope for funding and for publication in reputable academic journals (Graham 1978).

As an aside to the activities of the private critics, one may query the prediction of George Orwell that by 1984 the control of thought would be in the hands of the state. It has turned out instead that in the West the pressures to conform come from private groups who are claimants of a certainty of rightness which is above scientific findings and for that matter above law.

Turning to the new anti-Darwinism, the general modern charge, which reaches back a century for its attack on Darwin, is that he was a product of his times born in the England of laissez-faire capitalism. Presumably, like citizens of all ages, he did have the bias of his times, surely a stricture that could be universally applied. His critics have developed a sort of natural-selection-in-reverse theory, which is that Darwin looked at the structure of human society in England (so-called social Darwinism) and then applied it to nature generally (Gould 1977). It is conceded by the critics that Darwin himself did not say that nature was constructed according to the business principles of early capitalism. But Karl Marx did. He wrote:

It is remarkable how Darwin recognizes among the beasts and plants his English society with its division of labour, competition, opening up of new markets, 'invention' and the Malthusian 'struggle for existence'.

Marx was an admirer of Darwin and asked him to accept dedication of the second volume of *Das Kapital* but Darwin declined.

The overt attacks on Darwinism have come, first from the Right and latterly from the Left. The early critics of human evolution were church people who objected to Darwin as a materialist who threatened their established religious systems. Under the climate of materialism which had come into vogue in Darwin's time, his ideas flourished and were accepted and his opponents were vanquished.

In recent years the vigorous new assaults on the study of human evolution have been made by biologists of the radical Left, comprising an anti-Wilsonian center of Harvard heretics. Among the more equal of the officially unled group are Richard Lewontin and Richard Levins (Allen 1975; Wade 1976). It is sometimes said that the new objectors to Darwinism differ from those of the past century because they are led by practicing biologists who are proponents of social change rather than stability. But the difference disappears when it is realized that the new assailants of natural selection are fundamental Marxists who, like the Bishops, are fearful that their particular version of Truth might not survive the results of free scientific research.

The anti-Darwin position might be summed up in this way. One hundred years ago the Bishops objected to Darwin on the ground that his ideas degraded the quality of man's spiritual life and contradicted the Book of Genesis. Today the Harvard group object to Wilson because his ideas are thought to reduce the incentives for good behavior and contradict the theory of natural altruism which is basic to the Book of Marx. Both groups seek more agreeable ideas about the nature of man than science is likely to produce. Both want science to conform to non-scientific postulates.

The acceptance of Darwinism was aided in his time by the general approval of free-enterprise capitalism. Today the situation is reversed and contemporary criticism of natural selection as applied to man, derives its plausibility and effectiveness from disapproval of a human world of unrestrained competition. Darwin upsets the Left, according to whom the behavior of animals ought to be presented as showing a socialist ideal of equality and sacrifice for the general good. Mutual aid or altruism becomes the theme. It is desirable among humans and it can be observed among social animals.

Certain small birds, robins, thrushes and titmice for example, warn others of the approach of a hawk by a distinctive whistle (Wilson).

The balance between heredity and environment could be examined using evidence derived from any of our elemental bases of behavior: of sex and the family, of aggression and possession, of race relations, of food habits, or of altruism and religion. I have chosen religion because it invites a comparison between the early at-

tacks on Darwin and the recent ones on his successor. My attribution of contemporary opposition only to Marxists is also a selective simplification; many groups suspect that Wilson will be interpreted by conservatives as offering implicit approval to one or another undesired class structure. Workers against group prejudice, for example, are outraged to be told that our social tendency to form small, defensive class units of a few dozen families, may have some hereditary basis.

One more aside: the attacks on evolutionary discoveries could lead easily to a denial of evolution itself, and so allow the advocates of Genesis to say "We told you so". It would be a weak debating position to deny Darwinism but affirm that evolution had indeed occurred through some mechanism not yet understood.

Altruism and Religion

My own introduction to this section came many years ago from remarkable papers published by Trotter in 1908 and 1909. As he tells us, there are some animals whose conduct can be generalized very readily into the categories of self-preservation, nutrition, and sex, for instance the tiger or cat. The three solitary drives or primitive instincts, attain their maximal activities only over short periods of time and in special circumstances, and are fundamentally pleasant to yield to. When the circumstances are appropriate for yielding to one, the others automatically fall into the background, so that they are only infrequently in conflict.

The behavior of other animals is more complex, for example the dog, with his conscience, his humor, his terror of loneliness, and his devotion. A little examination will show that the animals whose conduct is difficult to generalize under the three primitive instincts are gregarious. Gregariousness then, is to be taken as a major biological instinct. Trotter, following Karl Pearson, holds that there have been two very striking advances in complexity and in the size of the unit upon which natural selection acts. These are the passage from the unicellular to the multicellular, and from the solitary to the social. The appearance of the herd instinct introduces a conflict with the other three, since its sanctions inhibit physically pleasant acts and ordain deeds that may be unpleasant.

It is a corollary of gregariousness, expounded originally by Pearson, that human altruism is a natural instinctive product. Man is altruistic because he must be, not because reason recommends it, for herd suggestion opposes any advance in altruism. When it can the herd executes an altruist, not of course as such, but as an innovator.

And now let us return from the London of 1908 to the Harvard of 1978. As Wilson notes, generosity without hope of reward is the rarest and most cherished kind of human behavior. However, any study of the evolutionary basis of self sacrifice and altruism is complicated by the many 'unselfish' acts that are products of social development rather than of genetic inheritance. Wilson calls the former 'soft core' or culturally evolved altruism, the good deeds that smooth the social contacts of our daily lives. It is the predominant variety, in which the 'altruist' expects rewards for himself and his relatives, and its examples are too familiar to warrant extended treatment. Wilson rather cynically lists its psychological vehicles as lying, pretense, and deceit, including self deceit.

'Hard core' or genetically explicable, unselfish, kinship altruism is restricted to helping close relatives, and declines in intensity as relationship becomes more distant. It is reasoned that the Darwinian advantage of the hard-core altruism of an individual lies in the improved chance of survival of his closest relatives who carry the same generous genes. Hard-core altruism or nepotism is an enemy of the development of civilizations beyond the small-tribe size. Family style cooperation would soon reach its upper limit and be replaced by the imperatives of blood and territory.

Geneticists have had difficulty in finding a satisfactory explanation of how kinship altruism can be expanded to take in the large-scale sacrifices observed, for instance, in national wars. Wilson, however, postulates that genes of religion enter here to permit hard-core altruism to co-exist with large civilizations. For religion, with its system of supernatural rewards, bridges the gap between individual aggression and acceptable behavior within national groups. The third-century dictum of Tertullian that "The blood of martyrs is the seed of the church" and its contemporary reiteration by the Ayatollah Khomeini of Iran, intimated that the purpose of sacrifice is to raise one human group over another. The effect of the policy has been to sanctify and channel individual aggression and bloodshed into the socially acceptable direction of large-scale war. To accept the probability that supernatural religion has an hereditary basis is a blinding flash of the obvious. It clears up at once the difficulty of adding the existence of group-selection altruism to the already genetically reasonable kin selection. The reward expected for the hard-core altruism of martyrs and patriots is to be obtained after death in a future world.

Biologists have not found any series of fossil remains which offer clues as to when and what practices related to religion and immortality entered the behavioral patterns of our hominid ancestors. As speculation on the question we may recall that the primary instinct of self-preservation includes resistance to death and the fear of death. Superimposed on this from among the herd characteristics is kinship altruism which extends the personal concern about dying to take in our relatives as well as ourselves. With the beginnings of man-like intelligence come thoughts about the future and how to ease the terror of passing, by exercises of propitiation towards whatever spirits may be in control of this major event. The evolutionary value of religion would lie in the strengthening of the bonds of unity within the tribe, enabling it to be more effective in war as well as in the hunting-gathering practices.

No parallels have been observed between human religious practices and behavior patterns of other social animal groups. The usual comparative studies have not been available, through which to determine the possible evolutionary advantages which were originally conferred on our ancestors by the development of the ceremonies. The first evidences we have of supernatural belief are shown by the intentional burial arrangements to be seen in early human graves. Sixty thousand years ago Neanderthal people in Iraq decorated a grave with seven species of flowers having medicinal and economic value, perhaps to honor a priest (Solecki 1975).

From the beginnings of divine belief, authorities have traced the expansion and utility of organized religions which accompanied the change from hunting, fishing and nomadic herding into agriculture, some 10,000 years ago. Farming required a more reliable water supply than on-the-spot rainfall. Wittfogel documents in detail how the earliest civilizations, with their structured societies, originated around rivers, where elaborate and parallel class structures arose. The systems were first described for the East, and since then similar civilizations have been studied in Mexico and elsewhere in the Americas. Theirs were despotic governments whose heads included a ruler, peace chief, war leaders, and priests. Commenting on the systems Karl Marx noted that "The necessity to calculate the periodic movements of the Nile created Egyptian astronomy and with it the rule of the priest caste as leader of agriculture". (*Das Kapital*, vol. 1).

The prestige and maintenance of power by the rulers, were closely linked to that of their divine protectors, who were eager to bulwark the legitimacy of the heads of state by underlining their supernatural support. The government engineers who created canals and waterworks also constructed palaces and temples to provide the supreme gods and their earthly functionaries with adequate surroundings for worship and residence.

From the dawn of the river civilizations it was upon the head of state that the magic powers of the commonwealth converged. He was a god, or the descendant of

a god, or a high priest with divine powers. He attached to himself and the government the symbols of supreme authority. Religious functionaries were the best educated class of society and were entrusted with many administrative and fiscal tasks. Through the priesthood the ruler could claim divine sanction instead of using force to assist in keeping peace; the distinction between politics and religion virtually disappeared, as today in the Iranian revolution.

Varieties of Salvation

Discussions about the control of man's behavior in this world by the will of genes, invite comparison with the theological doctrine of predestined salvation or damnation of souls in the next world by the will of God. Marxist theologians do not accept gene predestination, but rather affirm that Marx wills the salvation of all souls. Capitalists however may be damned by reason of their resistance to the grace offered them. The natural selection of Darwin (who did not himself write on human behavior) would reject the role of free will and imply that from eternity some souls are foreordained to success and others to failure. Wilson, a modernist, teaches that predestination is consistent with free will, since an individual is moved to behave according to his nature.

The position of Wilson's Harvard-centered critics seems to set up a distinction between our earth-bound human bodies with gene controlled animal functions, and something comparable to a soul through which desired motives can be evoked, and where heredity through natural selection no longer operates. By some philosophers the soul has been seen as a useful element in a system of ethics, and a worldly soul would be equally useful to biologists and others who did not wish to confront unacceptable scientific directions.

From the Left it is held that people, free from the blight of heredity, can be brought by indoctrination into the attitudes and behavior towards social equality that socialist theory requires them to have. (It will be recalled that in earlier times the Russians denied the general rules of heredity, as the name of Lysenko will bring to mind). The relatively scholarly recent attempt to undermine Darwin has turned to active hatred of Wilson's supposed claim that human beings are fixed, in an important fraction of their behavior, by their genes.

The pivotal indictment against Wilson is that he follows Darwin as the new leader of the long parade of advocates of biological predestination, whose work has served to excuse society from the acceptance of its responsibility for social problems. Such people provide the scientific base for expectation that the world will continue with existing social arrangements which include racial and anti-feminist prejudices, genocide and the rest. So even if Wilson's argument is right, is not research in sociobiology so fraught with the possibility of misuse that it should be stopped? Scientists in this field, it is asserted, must be held accountable for the political consequences of their academic activities, such as policy towards discrimination, militarism and social injustice. Theirs is indeed a heavy burden, to be escaped only by offering up their souls to Marx and coming forward to be born again.

The Future of Truth

The belief that the natural sciences would fill the emptiness left in the human spirit by the decay of religion was one of the major forces bringing about the decay.

To pragmatic thinkers the rise of the sciences was logically inseparable from the decline of religion. As Marx argued, religion itself would be recognized as having been little more than a naive, anthropomorphic attempt by the human species to understand the natural world and its many enigmas. By moving from the spurious explanations of theology to genu-

ine scientific understanding, man would satisfy the cravings of the human spirit and of the human soul for truth.

But can science assuage the nostalgia, the hunger for the absolute? What, today, is the status of the classical concept of truth? There is, for the first time in the Western tradition, an incongruence, a coming out of phase, between truth and human survival, between the rational pursuit of truth and contrasting ideals of social justice. It is not only that the truth may not make us free, but that it may destroy us. (Steiner)

How should we respond to the political and social implications of the dilemma? Should we say with the antagonists of Wilson's Darwinism: we are not interested in your results, we do not even want to know them. Society has not reached a point of balance, in which it can handle that kind of dynamite. Stop your research. We won't finance it. We won't accredit your laboratories. We won't give degrees for theses written in that field. Or do we say, on the contrary, all right, go ahead, pursue your research to whatever end of truth it leads. And if the end is totally unbearable in moral terms, too bad, that's how the universe is built and we simply cannot stop research.

Wilson's solution is to recognize that religion as well as altruism is to be considered as part of our genetic inheritance, which will make it respectable for materialists to adopt. He hopes to abolish the dilemma by bringing biological thought into the center of the social sciences and humanities. Recognizing that religious mythology will remain with us, he offers the evolutionary epic as probably the best base for a myth that we will ever have. Its particular merit is that scientific materialism can rearrange its great goals from the pursuit of pure knowledge.

The social scientists and humanistic scholars, not omitting theologians, will eventually have to concede that scientific naturalism is destined to alter the foundations of their systematic enquiry by redefining the mental process itself.

The rituals of religion, especially the funeral rites and the sanctification of nationhood, are deeply entrenched and incorporate some of the most magnificent elements of existing cultures. They will certainly continue to be practiced long after their etiology has been disclosed. The anguish of death alone will be enough to keep them alive. It would be arrogant to suggest that a belief in a personal God will disappear. (Wilson)

There have been many other proposals for secular, materialistic religions. One wonders how we have come so far without having the environment presented as a claimant to status as the real, all embracing, formal mythology. Some have made approaches to the idea (Hayes 1976). Environmental idealism is rooted in our Western religious traditions, according to which the quality of our surroundings has fallen, because of our sins, from some Garden of Eden ideal to its present deplorable state. Through our faith and work it is eventually to be redeemed to new glory (formerly only in Paradise, now thought to be awaited in this world).

And so one could go on and on through science-based theologies. But in the end the essential fault remains: no matter how much you fiddle with definitions, materialism and myth remain complementary if not contradictory terms. In the face of real human needs and experience both have failed in the totality test.

Science cannot really satisfy our nostalgia for the absolute because the disinterested pursuit of truth, subject to logical constraint, is not a universal one. Science has withheld recognition of the other vision of truth, beyond rational grasp, or experimental control; this is the mystical tradition, the part of Asia inside Western

man. The churches have fought for ownership of the mystical tradition, claiming that any 'truth higher than truth' comes under their control; it is revealed to man by divine intervention. And science, in the heat of its general struggle against the supernatural, has been led to overstate its own case; has pretended that it can offer total explanations; has neglected to develop an alternative mode of thought and feeling.

Although science's brand of truth cannot offer a complete picture of man, and hence is found wanting as a substitute theology, it does supply fully, the need of half the brain, and it might use the new sociobiology in its possession to buy half ownership in a more comprehensive mythology. At stake is the most interesting question in the world today; whether our civilization, or our species, or for that matter all higher life, can be saved from imminent extinction. Can the trick be accomplished by channeling the primary instincts, moderated by family ties, through the religious genes, to bring about a strong enough unit of purpose among mankind to successfully oppose destruction? My own experience offers nothing to contradict the verdict given by Trotter at the end of the First World War.

Throughout the enormously long period during which modern man has been established on the earth human society has been left to the uncontrolled contention of constructive and destructive forces, and in the long run the destructive have always proved the stronger. Whether the general level of consciousness will reach the height necessary to give a decisive predominance to constructive tendencies, and whether such a development will occur in time to save Western civilization from the fate of its predecessors, are open questions. The small segment of the social process of which we have direct knowledge in the events of the day has no very encouraging appearance.

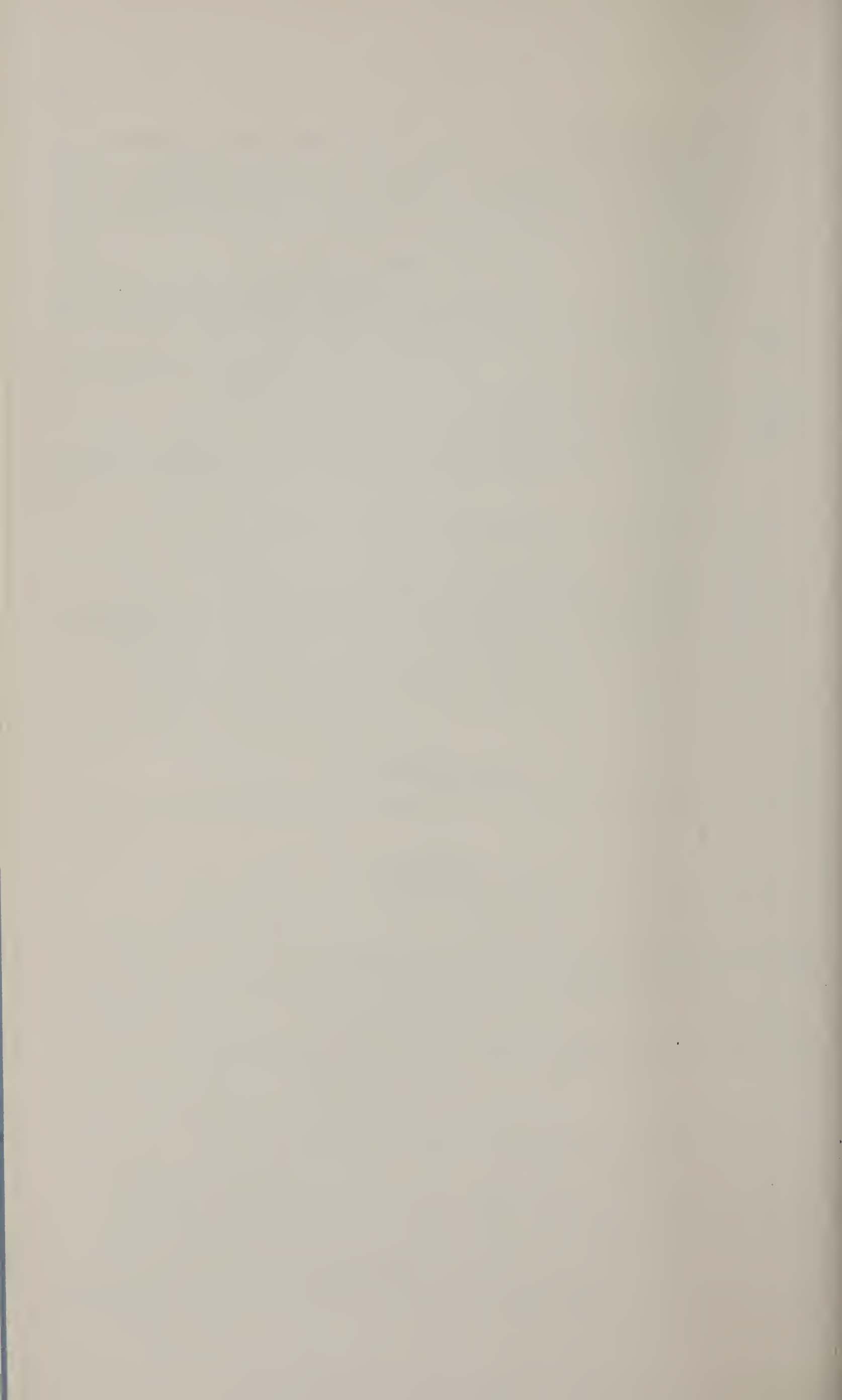
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AN UNUSUAL DEGLACIATION FEATURE NEAR THOMSON STATION, CUMBERLAND COUNTY, NOVA SCOTIA

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A small area near Thomson Station has tree-covered ridges and grassy depressions that appear to have been formed by burial of small ice blocks by glaciofluvial material during the final stages of stagnation of the last ice sheet.

Introduction

During the course of an examination of part of Cumberland County, N.S., I encountered a curious system of tree-covered ridges near Thomson Station, 7.5 km southeast of the town of Oxford. A reconnaissance study was made, and the conclusions reached are presented here.

The area in question is 0.8 km south of Thomson Station and lies just to the east of Colonel Brook and a short distance west of a bend in Tillit Brook (Fig 1). The region is covered by the national topographic series map 11E/12 and by black and white air photographs N.S. A18579-35/36, and color air photographs 75052-60/61. Colonel Brook is a tributary of Griffin Brook, which flows down the north slope of the Cobequid Mountains, but the area flattens near the junction of these 2 streams some 3 km south of Thomson Station. The topography in the vicinity of Thomson Station is gently undulating, but the locality under consideration is rather flat and lies at an elevation of about 30 to 35 m above sea level. It will be seen from Figure 1 that there is an abrupt drop to stream level at the 100-ft contour line surrounding the area. These are possibly kame terraces, which also flank the valley of Griffin Brook.

The area is underlain by rocks of Pennsylvanian age, consisting mainly of grey and red sandstones. Shales and conglomerate with some coal seams are also present. The bedrock is covered by till, capped by glacial sands and gravels that show evidence of re-working by water. The soils are loams and sandy soils, often very stony, assigned to the Hansford and Hebert series (Nowland & McDougall 1973). They are of poor agricultural quality, but have medium to high fertility for forest. At the present time they support second growth forests of red spruce, red pine, and jack pine, with some birch and balsam fir.

Description

Attention was drawn to the area by its cratered-like appearance on aerial photos (Fig 2). A visit showed the existence of numerous shallow circular depressions intersected by a system of sinuous ridges (Fig 3). The ridges themselves were at an elevation generally accordant with the surface of the surrounding area, so the depressions lie below this surface. The ridges support a jack pine forest with a high density crown closure. As a result, the floor is devoid of plant growth and carpeted with needles. In contrast, the depressions are practically devoid of tree growth except for an occasional birch or alder. The vegetation consists of moss, grass, and small shrubs.

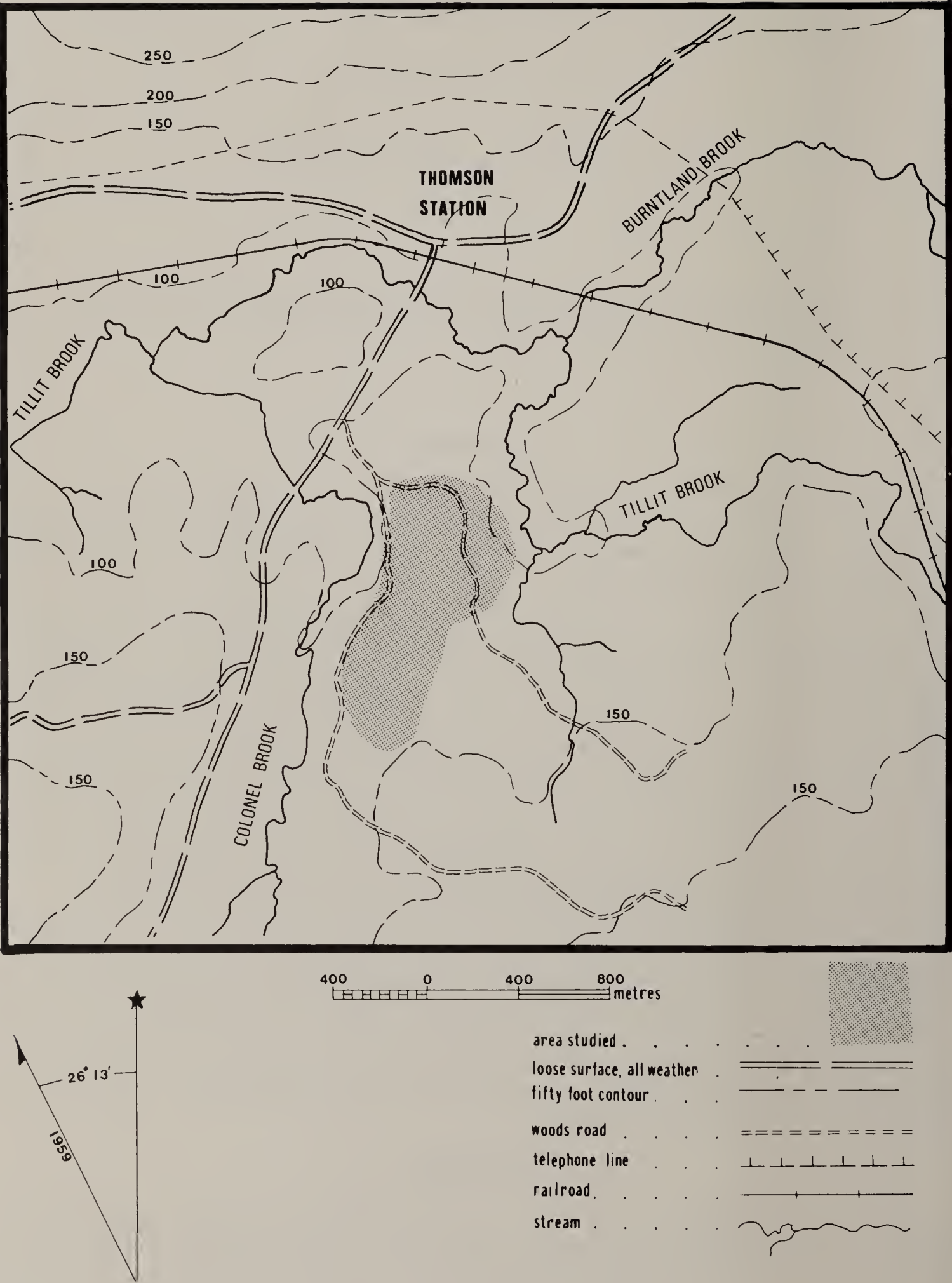


Fig1 - Topographic map showing the location of the study area.



Fig 2 - Stereo pair of air photographs of the area, showing the tree-covered ridges and treeless depressions (N.S. A18579-35/36).



Fig 3 - Sketch map of the area, drawn from the air photographs

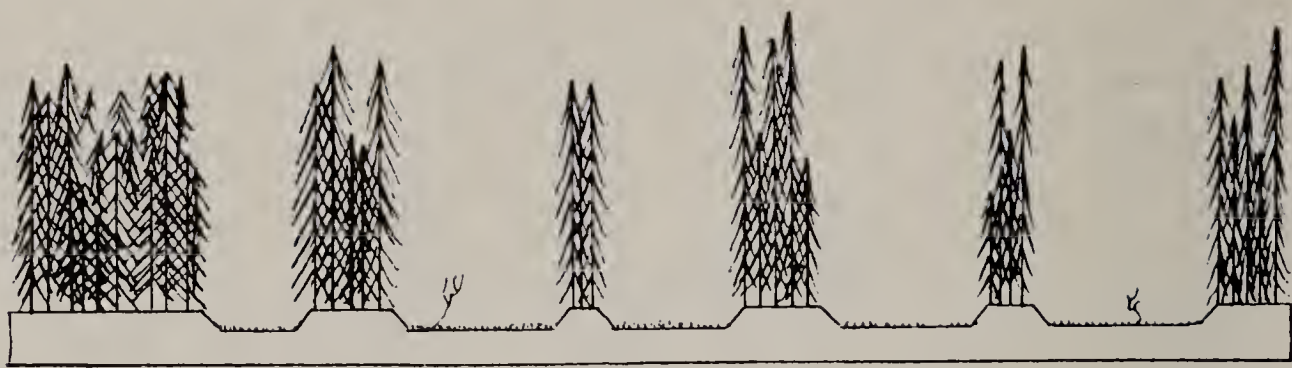
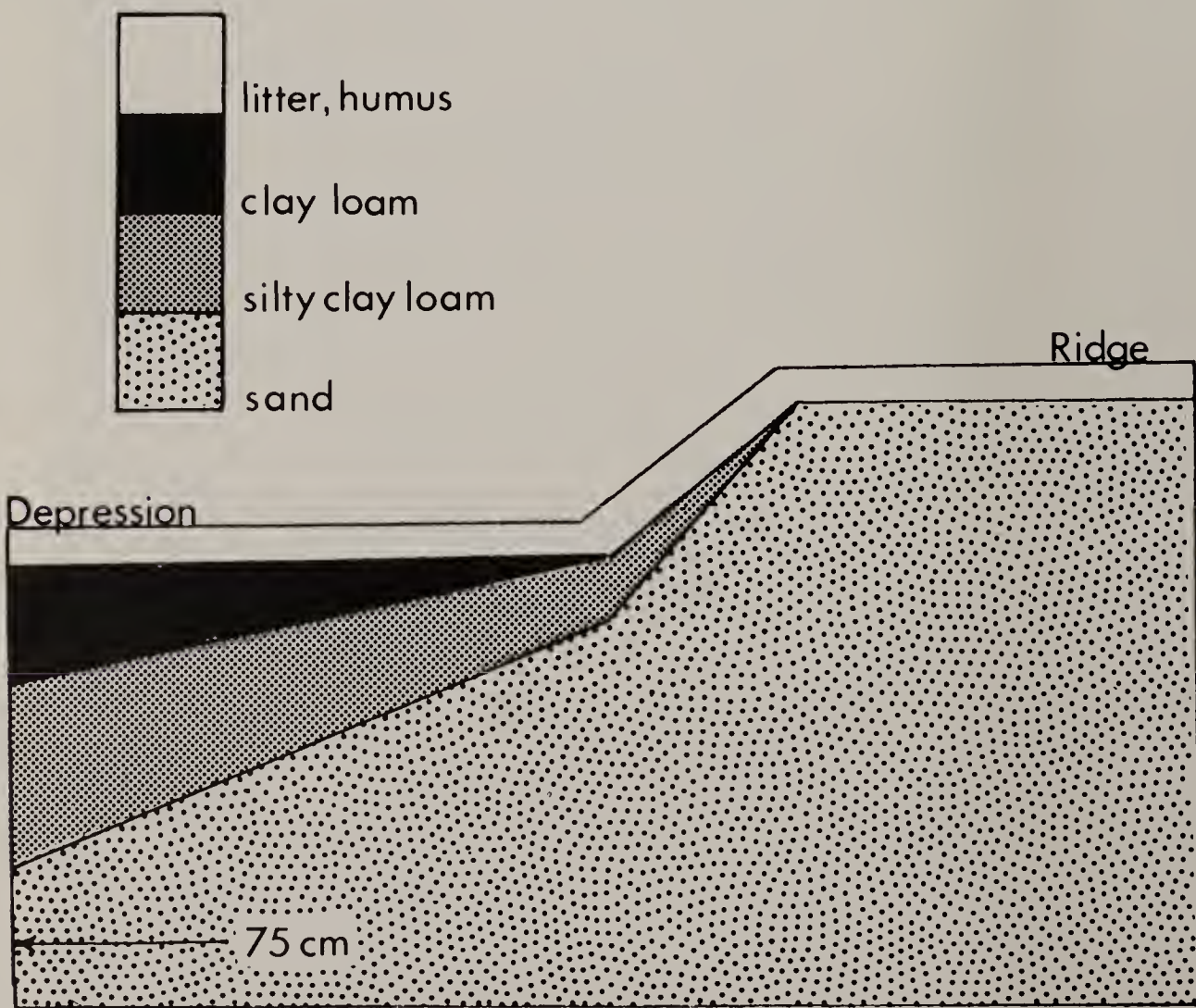


Fig 4 - Sketch profile to show the general relations of the ridges and depressions.

The border between each ridge and depression is sharply defined by a drop of 0.3 to 0.5 m in about the same horizontal distance. The tops of the ridges are flat, as also are the floors of the depressions (Fig 4). The depressions vary in size and details of their outlines but many are roughly circular and about 12 to 15 m in diameter.

After selecting a typical example of this system, a number of soil pits were dug. The results are shown schematically in Figure 5, with an inferred profile pattern.

In the center of the depression a 28 cm layer of black loam was found under 8 cm of litter, a fermented layer, and humus. Under this blanket lay more than 43 cm of silty clay loam with a strongly leached character.



SOIL PROFILE

Fig 5 - Schematic diagram to show the relations of the layers found in the soil pits.



Glacial till and residual ice blocks left by melting glacier

Glacial-Fluvial Outwash



Torrential meltwater loaded with sediment buries till and ice blocks

Channel flow

Kettles



Ice blocks melt, causing collapse of sediment covering. The diminished drainage has formed a new stream which has started to cut into the sediment.



Fluctuation of stream flow and load has caused downcutting and deposition of alluvial soil. The depressions have filled with decomposed vegetation and clay and silt from ground runoff.

Fig 6 - Diagrammatic reconstruction of the inferred origin of the features as small kettle holes resulting from the dissolution of buried ice blocks.

At the margin between ridge and depression, the pit showed 8 cm of black loam under a 5 cm layer of litter, ferment, and humus. The same silty clay loam was present with a thickness of 13 cm. This was underlain by more than 30 cm of a coarse red sand. On the ridge, a pit produced more than 50 cm of coarse red sand under 10 cm of litter, ferment, and humus.

Drainage ranged from poor in the depressions to well drained on the ridges.

Inferences

As the area shows strong evidence of glacial activity, it is suggested that these depressional features were formed in a manner similar to that of the more usual kettle holes. The inferred sequence of events is shown in Figure 6. Following the deposition of the basal till (which is exposed in Colonel Brook) the area was covered by residual ice blocks that became partly buried by coarse glaciofluvial sediment carried by meltwater from the dissolution of the glacier. These blocks eventually melted, leaving depressions that have been partly filled by silt and decomposed vegetation. Eventually they will be filled completely and disappear. Meanwhile, the damp environment in the depressions will only support moss, grass and occasional trees.

Acknowledgments

I am indebted to Dr. H.B.S. Cooke, Department of Geology, Dalhousie University for advice and for assistance with the preparation of this paper.

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LIMNOLOGY OF THE ANNAPOLIS RIVER AND ESTUARY: I. PHYSICAL AND CHEMICAL FEATURES

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Results of physical and chemical studies of the Annapolis River and Estuary during the summer of 1976 are presented. Since completion of the tidal dam at Annapolis Royal in 1960, the estuary has become highly stratified, with outflowing fresh water ($< 2\text{‰}$) overlying salt water of 16-24‰. A very narrow halocline and thermocline occurs at 4 to 5 m over most of the estuary. The salt wedge moves upstream during the summer months when river discharge is low, reaching > 25 km above the tidal dam. Owing to the lack of mixing, considerable oxygen deficits were recorded in the salt wedge. River discharge varied with rainfall with about 2 to 3 day delay. River waters were relatively high in chlorides, nitrates, and orthophosphates, and moderately well buffered. The consequences of installing a tidal power turbine in the causeway at Annapolis Royal are discussed.

Introduction

The province of Nova Scotia is, by any standards, both well watered and well drained. Precipitation falls in all months of the year and totals 100 to 150 cm. yr⁻¹ in different parts of the province. The water collects, briefly, in more than 10,000 lakes and ponds, most of them situated on igneous rock in the southern half, and subsequently flows out to the Atlantic, the Gulf of St. Lawrence, or Bay of Fundy through a myriad of small and large streams. Most of the streams are short, flowing independently into common estuaries or directly into the sea along the more abrupt coastlines (Smith 1966).

Several of these river systems have, in the last half-century, been partially or completely impounded to produce hydroelectric power or control seasonal flooding of dykelands on the eastern estuaries. More than 60 reservoirs involving 16 river systems will be generating 355 MW when the Wreck Cove Project comes on stream this year. A number of major rivers, including the Shubenacadie, La Have, Annapolis, Margaree, Tusket, and Gaspereau, support important sport and commercial fishing activities based upon anadromous fish such as salmon (*Salmo salar*), striped bass (*Morone saxatilis*), shad (*Alosa sapidissima*), gaspereau (*A. pseudoharengus*), and smelt (*Osmerus mordax*) while many others are extensively fished for introduced trout (*Salmo gairdneri*). Last, but certainly not least, the rivers are also the recipients of the effluvia of our society: sewage, at best only partially treated, industrial wastes and the run-off from agricultural land and feed lots. It now seems probable that at least 1 river estuary will be used to generate electricity by manipulation of tidal water. It is surprising, in view of the manifold uses to which Nova Scotia's rivers have been put, that so little is known about their general limnological characteristics.

A recent study of striped bass spawning in the Annapolis River (Williams 1978) necessitated the accumulation of a substantial amount of background information on stratification, rates of flow, and physico-chemical properties of the river and its estuary. It seems appropriate at this time, when plans are under way to install a tidal power turbine in the causeway near Annapolis Royal, to review the information that has so far been obtained about this river. The present contribution summarises physical and chemical features, and provides a foundation for subsequent reports on fish distributions and benthic invertebrate populations.

Methods

Surface and bottom water samples were collected with a 2.1 l horizontal Van Dorn sampler at 4 locations (0.6, 16.7, 32.2, and 46.7 km upstream from the Annapolis causeway - Fig 1) in mid-May and at intervals of 2 to 9 days during June, July, and August 1976. Each sample was analysed for dissolved oxygen using the Alsterberg modification of Winkler's method (A.P.H.A. 1976). Total alkalinity, pH, chloride, sulphate, orthophosphate, nitrate-N, and turbidity were determined with a Hach DR-EL kit.

Vertical profiles of the river were obtained using a YSI model 33 S-C-T meter. Salinity and temperature were recorded at each meter depth at 14 stations between Annapolis causeway (km 0) and km 20 on 10 May. Salinity profiles were again obtained at 17 stations between km 0 and km 30 on 2 July. Additional profiles were taken for specific short stretches of the river on other occasions. At Bloody Creek (km 25), a site of particular interest, profiles were taken at intervals of 1 to 10 days between 5 May and 2 July in order to study the oscillations of the salt wedge as influenced by tidal and precipitation patterns.

The Annapolis River System

The Annapolis River originates near Aylesford (Kings Co 45°02'N, 64°50'W) and flows southwestward through the Annapolis Valley for about 142 km before discharging into the Annapolis Basin near Annapolis Royal (Annapolis Co 44°45'N, 65°29'W). Decrease in elevation over that distance is a little more than 40 m, and with such gentle slope the river meanders extensively. The Valley ranges in width from 4 km at its western end to 9 km near Aylesford. It is flanked on the northern side by North Mountain, a basalt cuesta of the Triassic period, 5 to 8 km wide with crestline elevations of 183 to 244 m above MSL. The south face of North Mountain is a steep escarpment breached at intervals by the ravines of small streams tributary to the Annapolis River. Flow is usually intermittent in these short tributaries (Hickox 1962; MacDougall et al. 1969).

To the south the valley is bounded by the South Mountain Highlands, a somewhat older (Devonian) granite batholith. The slopes of South Mountain are well dissected by drainage streams that ultimately flow into the Annapolis River. However gradients are moderate, and the Highlands contain innumerable lakes and boggy depressions resulting from impeded drainage (MacDougall et al. 1969). Most of the streams are permanent, having measurable flow all year and follow winding or meandering channels (Fig 1). About two-thirds of the 2130 km² of the Annapolis watershed is within the South Mountain Highland (Trescott 1968).

About 50% of the soils in the valley are developed on glacial till, 30% on glacial-fluvial material, and the remainder on estuarine deposits and stream alluvium, with some areas of peat and muck. Riverside soils from Annapolis Royal to Paradise consist of poorly drained silty loam and silty clay loam, but upstream from Paradise the soils along the river are excessively drained sands and gravel. Soils on the lateral valley slopes are very thin and bedrock exposures abundant (MacDougall et al. 1969).

The natural vegetation of the Annapolis Valley is a forest of softwoods or mixed softwoods and hardwoods, but this has been greatly modified by human activity. Very little undisturbed forest remains (MacDougall et al. 1969). Marine alluvium deposits beside lower reaches of the Annapolis River and Annapolis Basin have never been forested. Many of these areas were reclaimed from salt marsh by erection of earth dykes.

In 1960 the Annapolis River Tidal Dam was constructed near Annapolis Royal. It consists of a rockfill causeway and a central section built of open concrete caissons, the latter containing 2 sluice gates used to control water levels and a permanently open 3 x 7 m fishway. Tidal amplitude on the basin side of the dam ranges from 7 to

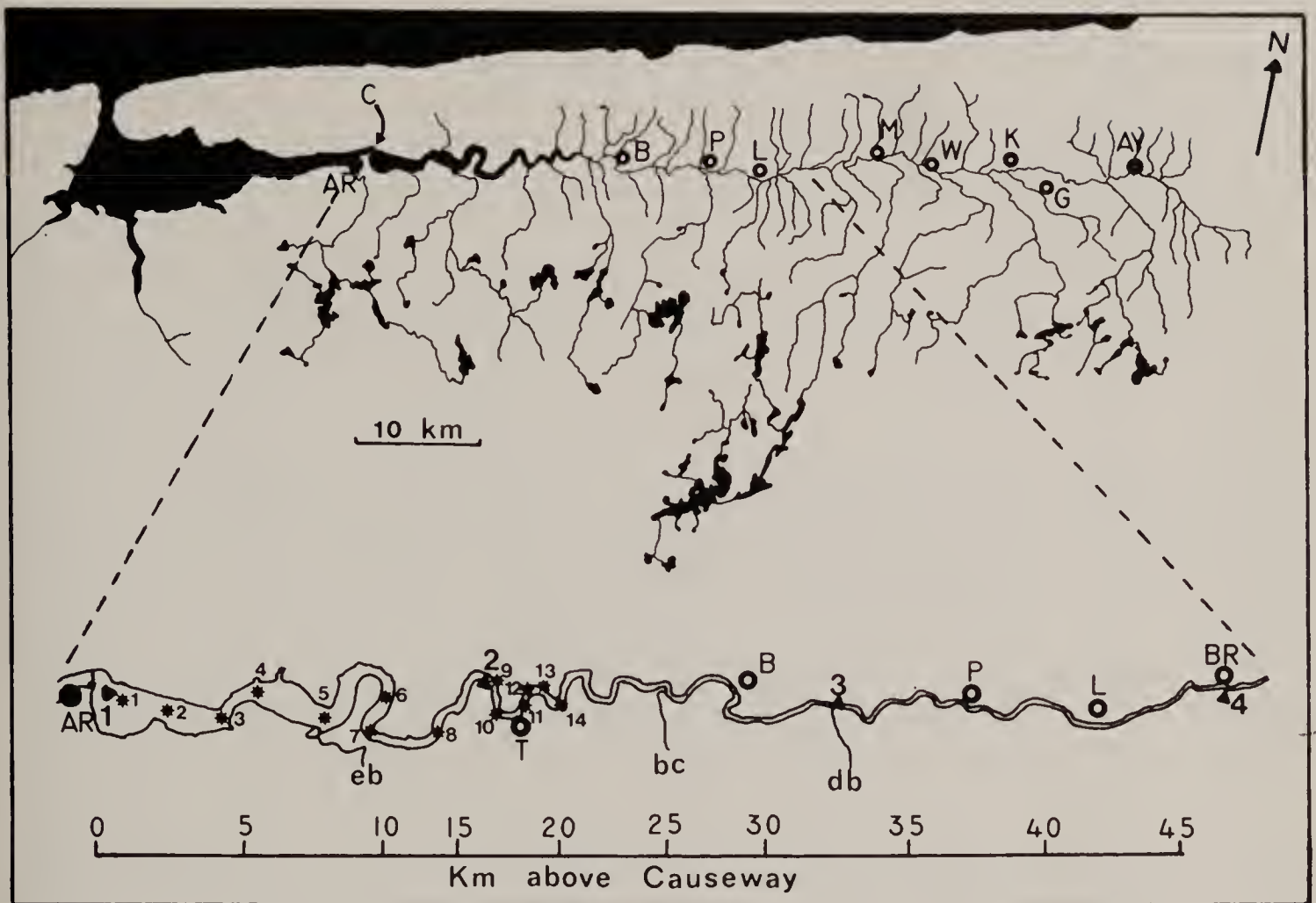


Fig 1. Upper: The Annapolis River System. Lower: Map of study area, slightly enlarged. AR - Annapolis Royal; AY - Aylesford; B - Bridgetown; BR - Brickton; C - Causeway; G - CFB Greenwood; K - Kingston; L - Lawrencetown; M - Middleton; P - Paradise; T - Tupperville; W - Wilmot; bc - Bloody Creek; db - Daniel's Brook; eb - Evans Brook.

▲ 1-4: Sample sites for water analyses;

* 1-14 Sites for 10 May salinity/temperature profiles.

Lower scale shows river distances above causeway for lower figure.

9 m. Prior to closure, the Annapolis River was tidal as far as the village of Paradise, but tidal range behind the dam is now usually controlled to ± 0.5 m (Jessop 1976). The dam eliminates need for the kilometers of running dykes formerly required to protect about 1740 ha of reclaimed marshland from tidal flooding.

Physical Features

A physical survey of the Annapolis estuary from the causeway to Bridgetown was done by Fisheries and Marine Service (Environment Canada) personnel in 1975 (Jessop 1976). The river upstream to Brickton was surveyed in 1976 as part of the present study.

The headpond above the dam is broad, 4.1 km in length by 0.7 to 1.6 km in width, and oriented about east-west. It is thus exposed to predominantly westerly winds that are funneled through the Annapolis Basin. Maximum depth encountered by Jessop in August 1975 was > 21 m about 1 km above the causeway. However, much of the headpond is 9 m in depth, the old river channel forming a relatively narrow trough that meanders for some 8 km above the dam to the southern side of the impounded area. The estuary narrows abruptly near Mochelle, widens to about 1 km at

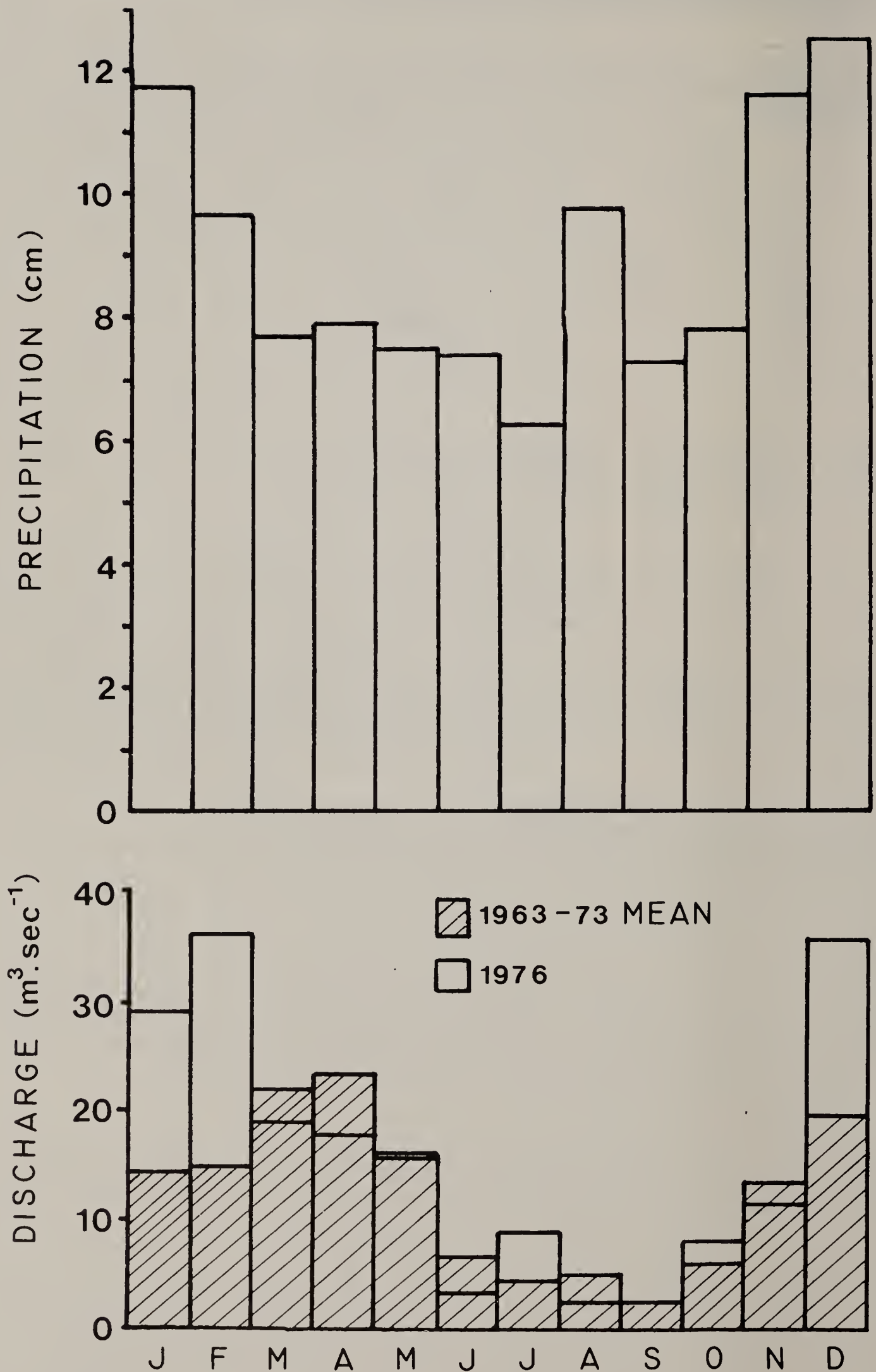


Fig 2. Total Monthly precipitation at CFB Greenwood, 1976, and monthly discharge of Annapolis River recorded at Wilmot.

Granville Centre, but then narrows again as it meanders around Pré Rond Marsh, where it is constrained between earthen dykes. Maximum depth at Pré Rond is 6 m. Depths diminish to 3 m between Tupperville (km 20) and Bridgetown (km 30), are generally < 2 m above km 30 and < 1 m above Lawrencetown (km 42).

Discharge of the Annapolis River has been recorded at Wilmot, about 80 km upstream from the causeway since 1963. The watershed monitored by this station is only 546 km² compared with the total of 2130 km² for the Annapolis system as a whole. The long term average monthly flow (1963-73) indicates a strongly seasonal pattern with maximum discharge in winter (Dec - Feb) and minima in mid to late summer (Fig 2).

This pattern corresponds fairly well with the long term average monthly precipitation as recorded for Greenwood 9 km away, except for the marked low in discharge during the summer. Obviously, much of the deficit is removed by direct evaporation, although some is used in mid-summer to replenish ground water supplies (MacDougall et al 1969). Total annual discharge at Wilmot in 1976 was $504 \times 10^6 \text{ m}^3$ (409,000 ac-ft) at a mean monthly rate of 15.9 m³/sec (563 cfs). These values are considerably greater than the long term averages of $400 \times 10^6 \text{ m}^3$ (325,000 ac-ft) and 12.68 m³/sec (448 cfs) respectively, and result primarily from unusually heavy winter snowfalls.

A comparison of the daily precipitation recorded at Greenwood with discharge at Wilmot for the period May to August 1976 indicates that the river responds with a 2 to 3 day delay (Fig 3). Surface water velocity measurements at 11 sites between Bloody Creek (km 25) and Lawrencetown (km 42) between June 10 and 19 indicated an average velocity of 0.32 m/sec (Williams 1978) corresponding to a daily distance travelled of > 27 km. These values were recorded at a period of low flow and thus indicate minimal response and conveyance time. Maximum velocity recorded during this study was 1.39 m/sec on 15 June, shortly after the very heavy rainfall of 12 June (Williams 1978).

Vertical profiles of temperature and salinity were taken at the 14 points between km 0 and km 20 on 10 May, 1976. At the station closest to the causeway (No. 1, Fig 1), a marked and progressive increase in salinity occurred as depths increased (Fig 4, 1). Surface waters were moderately fresh at 3‰, whereas near the bottom at 13.5 m salinity was 23 ‰. A distinct halocline was not present in this area, although increases in salinity were greatest between 2 and 5 m, over which depth range temperatures also declined from c 11.5°C in upper waters to 10°C at 5 m.

At Station No. 2, however, in shallow water (7 m) about 2.5 km from the causeway, the water column was distinctly stratified. The top 2 m exhibited salinities of 1 to 2‰ and temperatures of 12°C. This highly stratified structure was encountered as far upstream as km 8 (station 7) with narrow halocline and thermocline occurring at a depth of 4 to 5 m. Above km 10 the rapid shallowing of the estuary resulted in diminution of the lower saline layer until it was represented only by a narrow salt wedge lying on the bottom. This bottom layer was detected as far as Tupperville (km 18). Beyond this point on May 10 the river was uniformly fresh from surface to bottom and homothermal at 13°C.

Between 10 May and 27 June salinity and temperature profiles were taken at intervals of 3 to 10 days at 8 locations between km 16 and km 32 (Daniel's Brook) in order to monitor the furthest extent of the salt wedge. These data are recorded in Williams (1978). Until 12 June the salt wedge was detected at km 22, but no further. On this date it extended at least to km 25, and on 15 June was up to Bridgetown (km 28). On 27 June it had reached km 29 but was not present at Daniel's Brook.

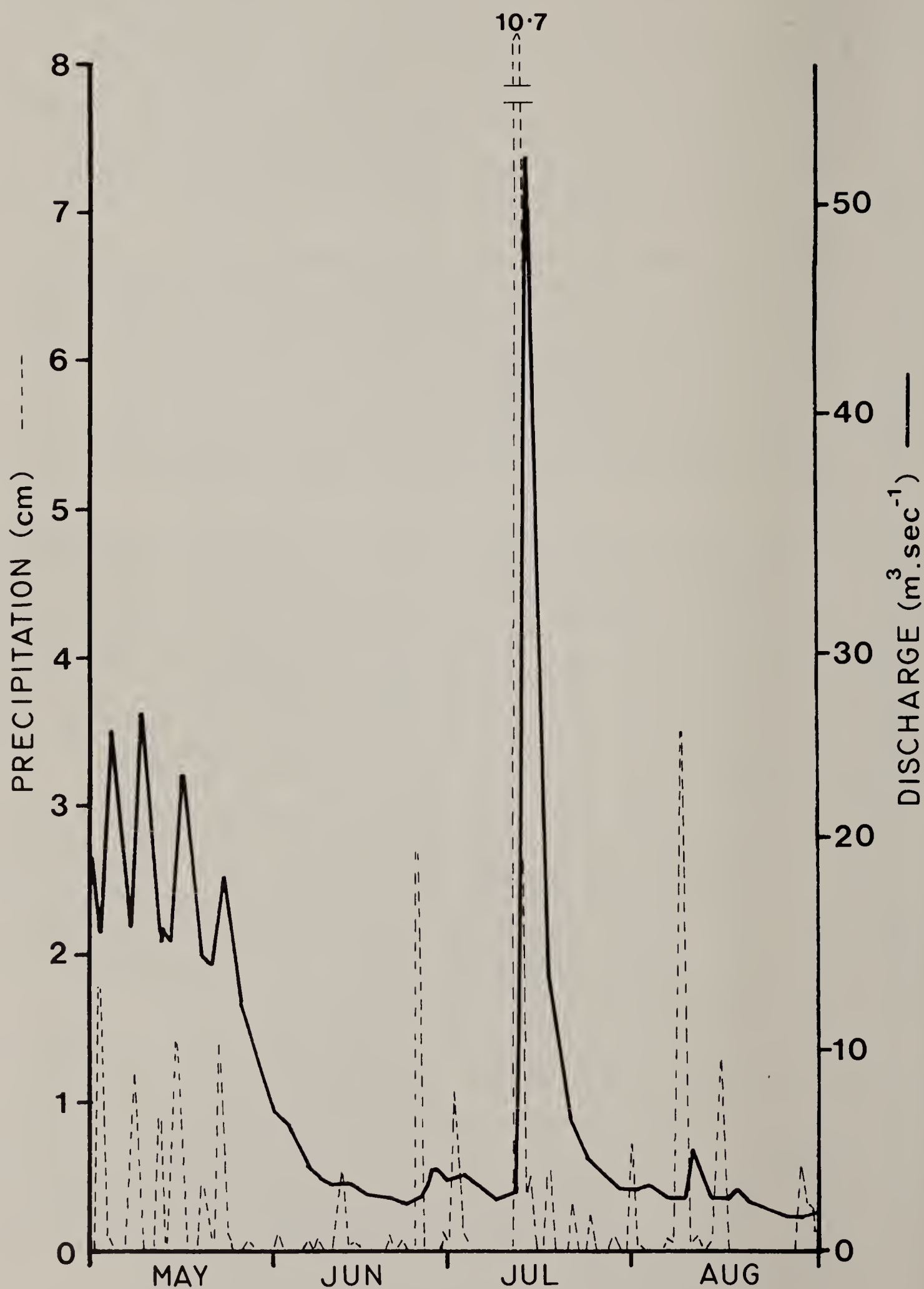


Fig 3. Daily precipitation at CFB Greenwood — and discharge of the Annapolis River at Wilmot — May-August 1976.

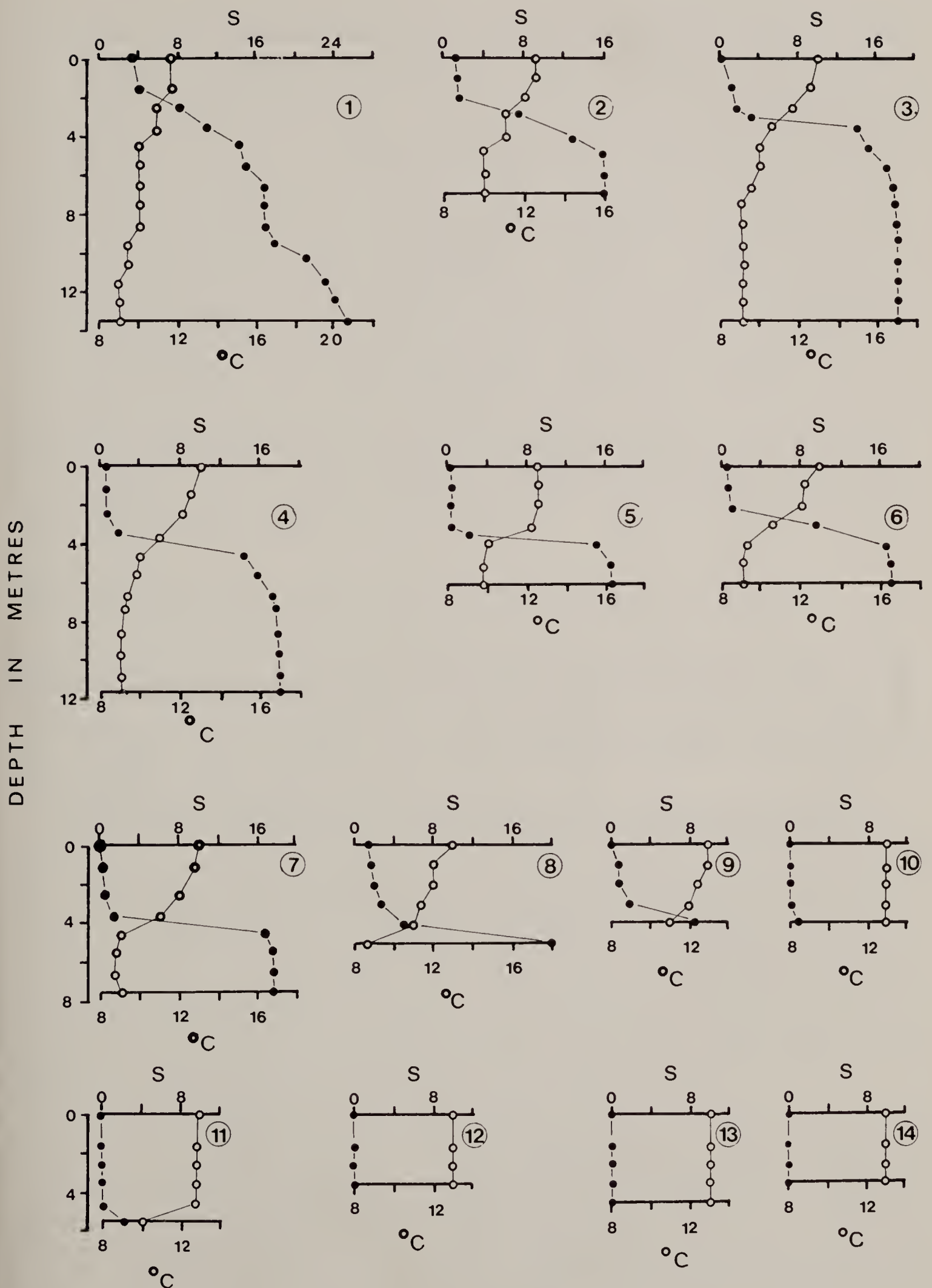


Fig 4. Salinity ($S^{\circ}/_{\infty}$ •—•) and temperature ($^{\circ}\text{C}$, o—o) profiles of the Annapolis River, 10 May 1976. Sample station (1-14) locations in Fig 1.

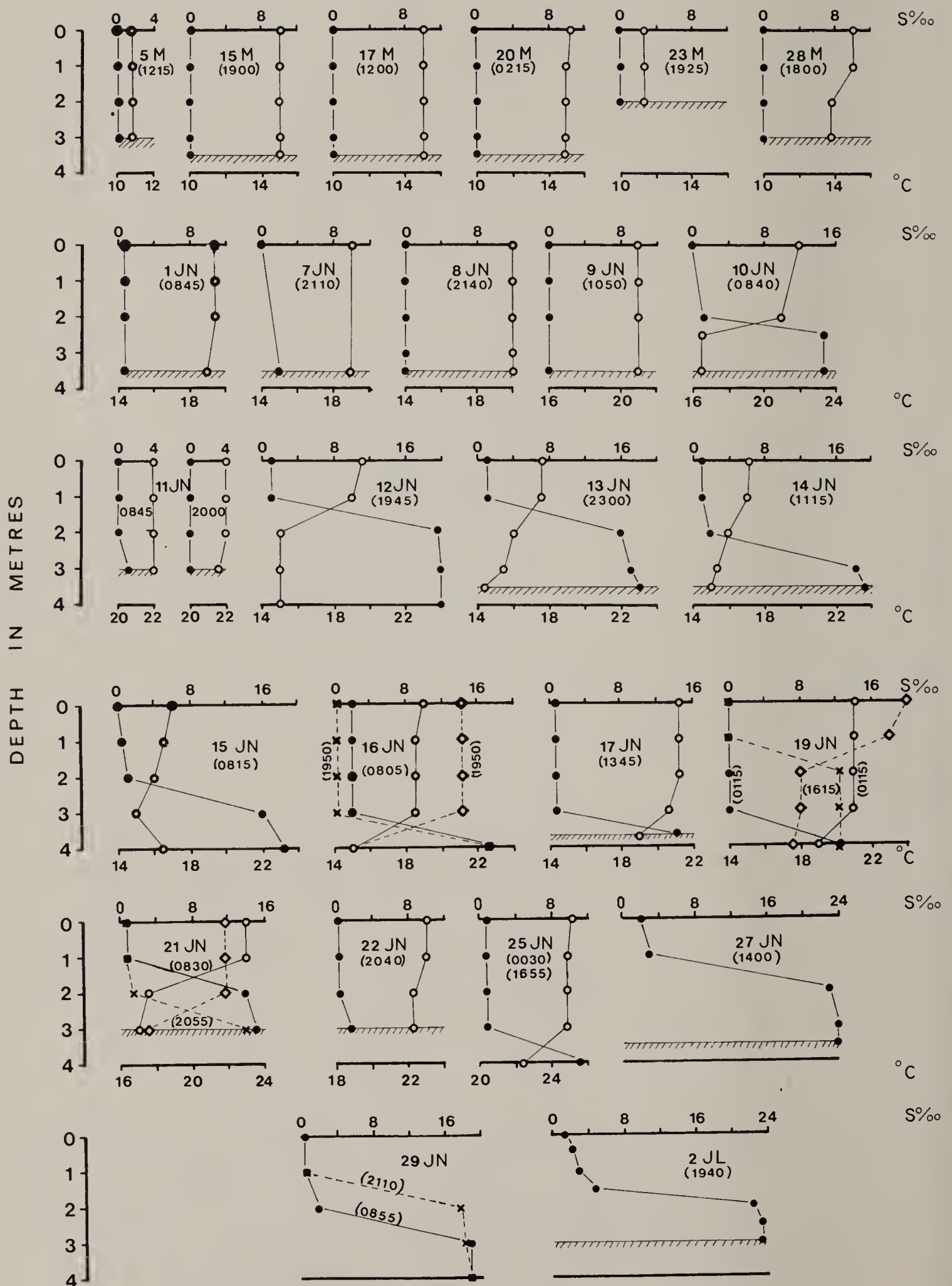


Fig 5. Salinity ($S_{\text{‰}}$, •—• x—x) and temperature ($^{\circ}\text{C}$ o—o, $\diamond$ — $\diamond$) profiles at Bloody Creek (km 25) during May (M), June (JN) and July (JL), 1976. Sample times (in h) given in parentheses. Recorded depth varied according to state of tide, river flow, and precise sample point.

The results indicated a progressive upstream movement of the salt wedge as water levels declined. However, on 22 June, during an extended period of low flow ($< 3 \text{ m}^3/\text{sec}$ at Wilmot from 15 June), the salt wedge could not be detected at Bloody Creek (km 25) although it had been there a few days previously. It was apparent that tidal movements also influenced the uppermost extent of the salt. By 2 July the salt wedge had reached Daniel's Brook. It was not detected above this point at any time.

In order to examine the influences of tidal movement and river discharge on salt intrusion, we recorded vertical distributions of salinity and temperature near Bloody Creek at frequent intervals from 5 May to 2 July. The results are given in Figure 5. The salt was first detected at this station on 10 June (0840 h), was absent on 11 June and returned on 12 June. It was absent again on 22 June, but present on all other days examined. The thickness of the salt wedge, however, varied markedly on 19 June, where samples were taken at times close to low and high tides. Most other sample intervals were multiples of 12 h and thus corresponded approximately to the same stage of tide.

Records of turbidity were obtained at frequent intervals at 4 locations between the causeway and Brickton (km 47). Turbidity in the river and in surface waters of the estuary was generally low ($< 50 \text{ JTU}$). Saline waters, however, were usually more turbid as would be expected in tidal regions off the Bay of Fundy, although a sharp and consistent decrease in turbidity took place during mid-summer in bottom waters near the causeway (Fig 6).

Chemical Features

pH at the river stations (3 and 4) varied little during the study (Fig 7) from 6.2 to 6.6, and there was no significant difference between surface and bottom water. Below Tupperville (No. 2), however, while surface waters remained slightly acidic because of stratification, the lower saline water was circumneutral. Near the causeway (No. 1) pH values fluctuated around neutrality, occasionally with surface waters exhibiting slightly lower values. These instances probably indicate decreased mixing between riverine and estuarine water.

The dissolved oxygen (DO) values given in Figure 8 are at best only indicative of general patterns because samples were taken at varying times of day and tide, and solubility varies considerably both with temperature and salinity. At the 2 river stations, DO varied irregularly between 6 and 9 mg/l during most of the study, representing 70 to 100% saturation. There was no significant difference between surface and bottom concentrations. A general trend can be seen whereby O_2 saturation was inversely related to river discharge: at periods of low flow (eg mid-June and early August) the water was always close to saturation, whereas in early June and mid-July when discharge was greater O_2 saturation declined to 70-80%. Since temperature varied little during June to August ($20\text{-}23^\circ\text{C}$ at the times of measurement) these changes are reflected in the concentration values shown in Figure 8.

In the estuary, surface waters exhibited similar patterns of DO concentration to the river, whereas the underlying salt water generally showed much lower concentrations. Near the causeway DO remained close to saturation (94-105%) for the whole study period, both at the surface and near bottom. The lower concentrations in deeper water are thus entirely a function of temperature and salinity. At the Tupperville station, however, whereas the outflowing river water at the surface remained consistently close to saturation, the underlying salt water was frequently much undersaturated. This is undoubtedly due to the very stable chemical stratification in that part of the river, which prevented replenishment of oxygen withdrawn by biological processes. It is to be noted that the salt wedge reached as little as 44% saturation in mid-August. This degree of undersaturation, if persistent, would have considerable ecological significance.

Total alkalinity at the river stations was generally $< 30 \text{ ppm}$ except for a sharp in-

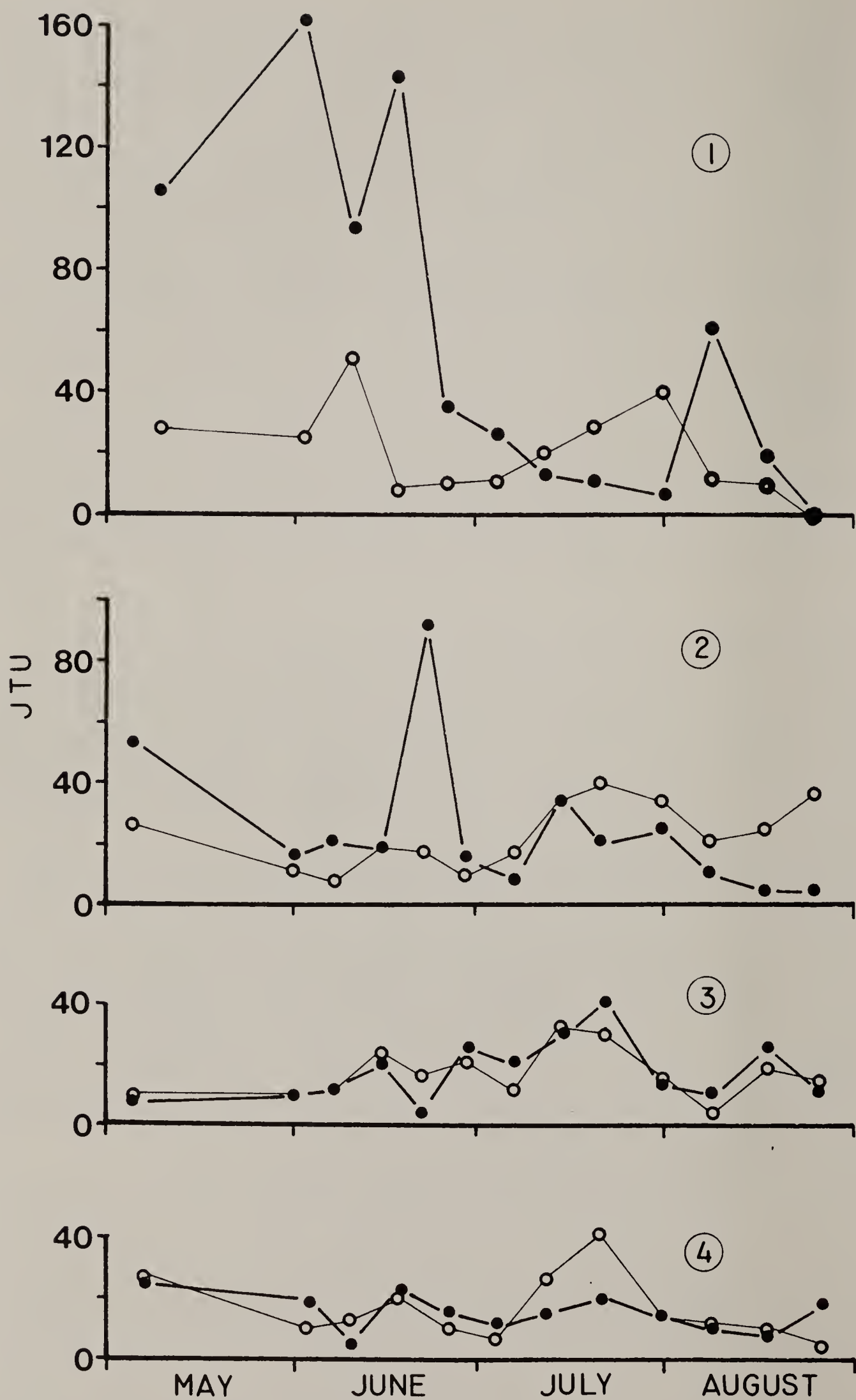


Fig 6. Turbidity (Jackson Turbidity Units—JTU) at Stations 1-4, May-August 1976 (•—• bottom sample; o---o surface sample). Sample stations (1-4) in Fig 1.

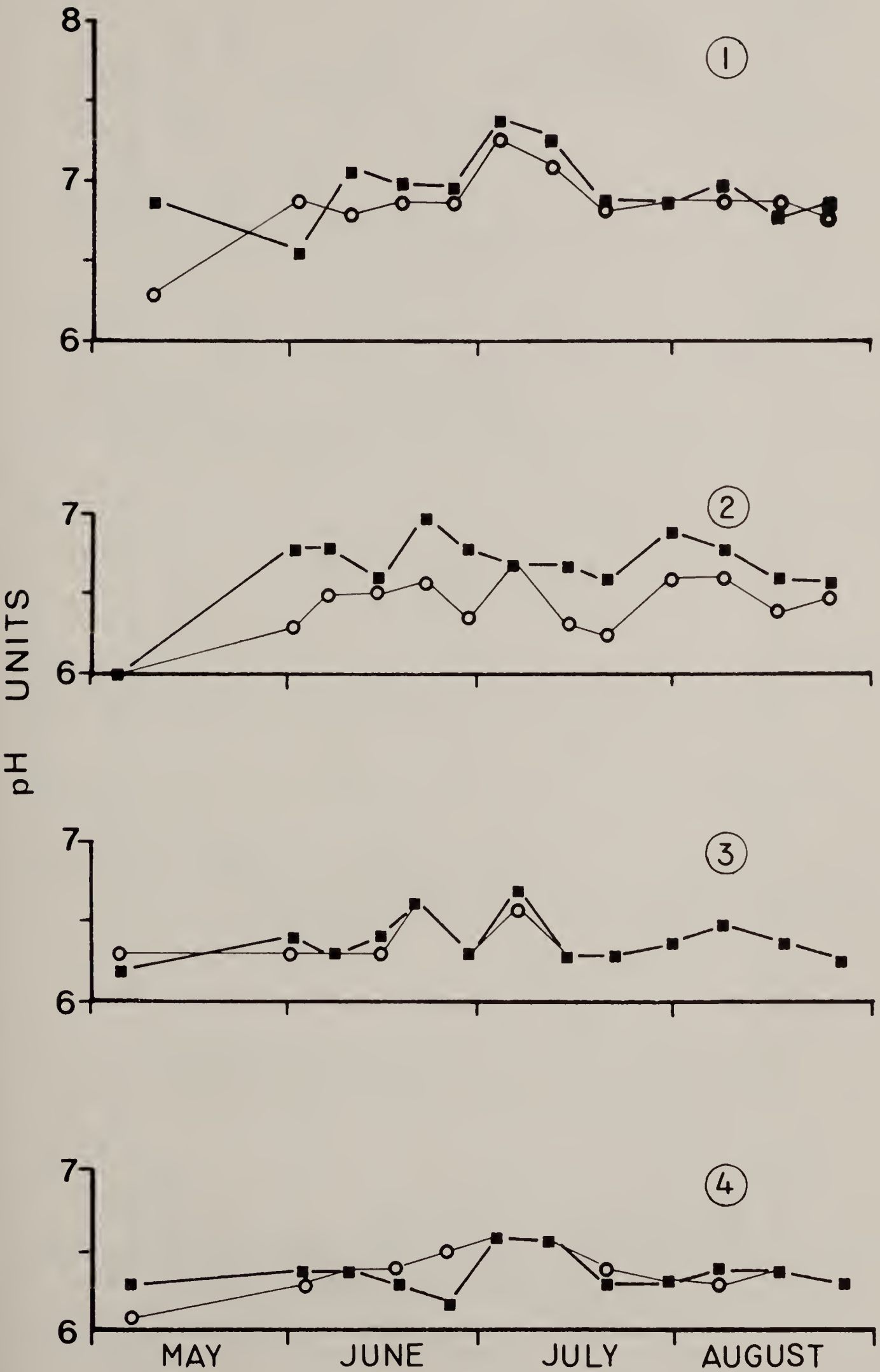


Fig 7. pH at stations 1-4, May-August 1976. (■ — ■ bottom sample; o—o surface sample).

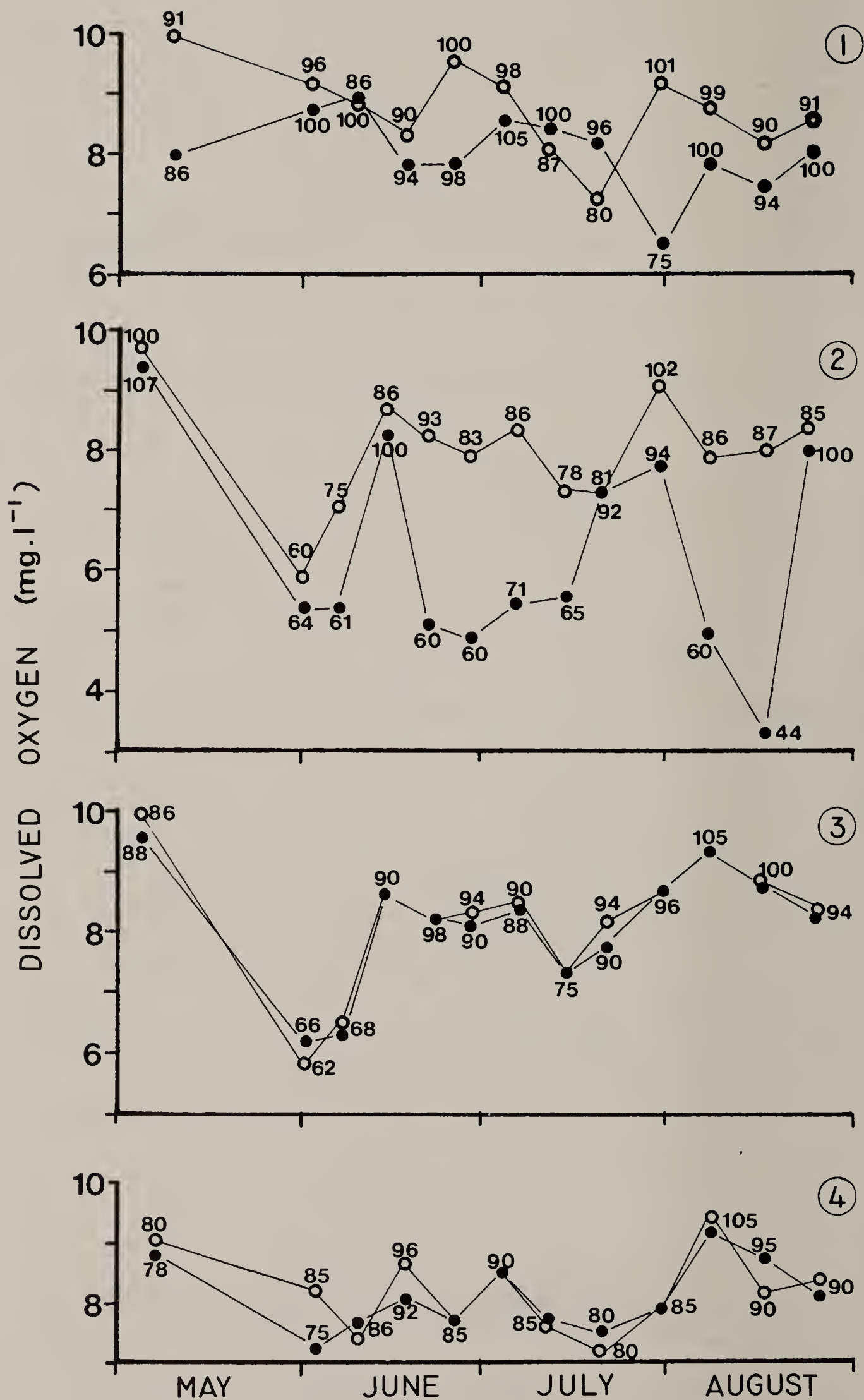


Fig 8. Dissolved oxygen at stations 1-4, May-August 1976. Numbers beside data points represent % oxygen saturation of water calculated from measured temperature and salinity (Symbols as Fig 6.).

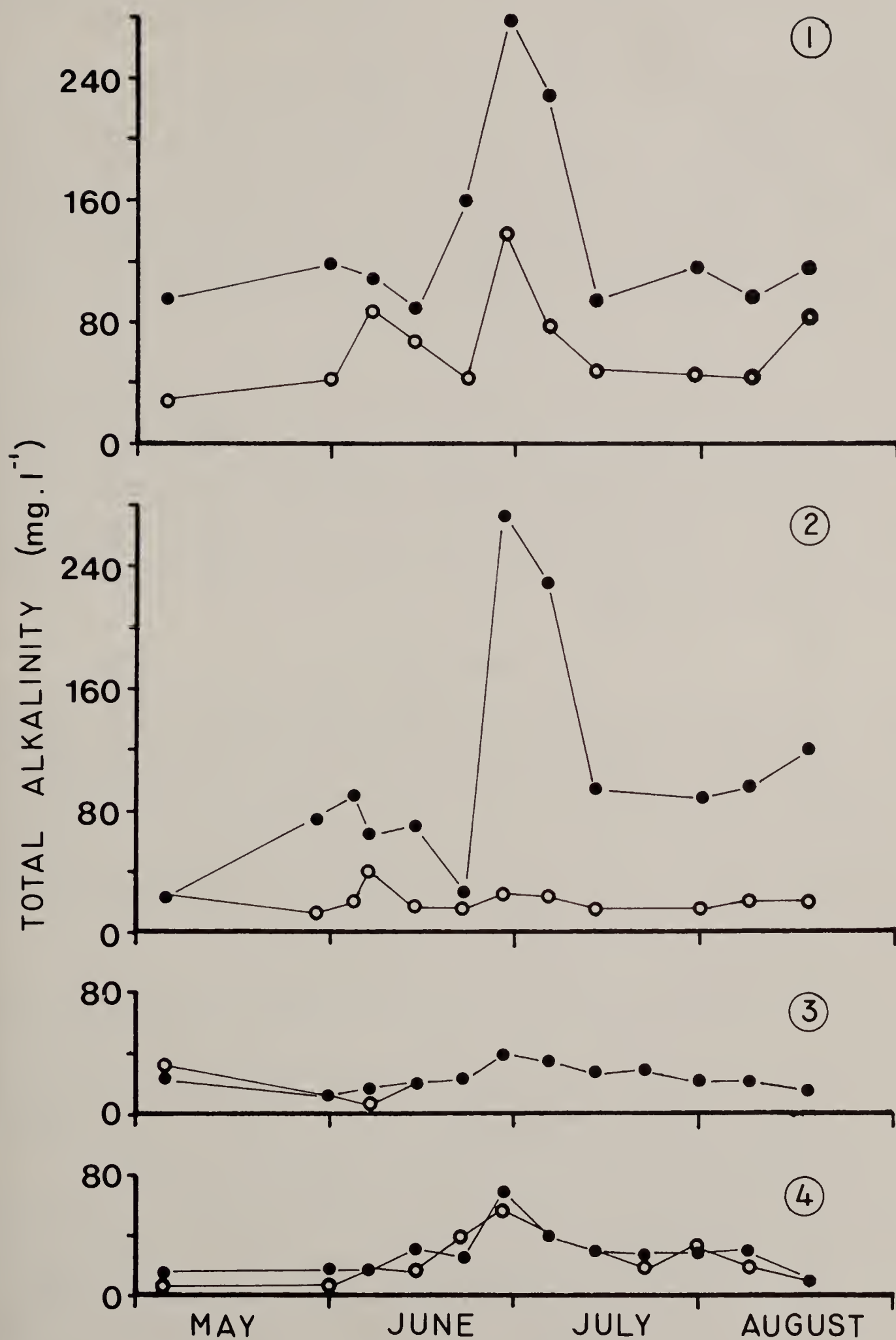


Fig 9. Total alkalinity (mg.l⁻¹ CaCO₃) at stations 1-4, May-August 1976. (Symbols as Fig 6.)

crease at the end of June (Figure 9). This rise appeared after a relatively long period of low flow, but cannot be unequivocally related to it. In the estuary, the strong rise in alkalinity in lower waters was coincident with the persistent and extremely stable stratification resulting from the decrease in river output.

Chloride concentrations in bottom water near the causeway varied little (Fig 10) as would be expected, since this water was derived almost solely from tidal water outside the causeway. Surface waters fluctuated between 2500 and 18,000 ppm in a manner suggesting a varying degree of turbulent mixing. At station 2, below Tupperville, chloride concentration increased as the salt wedge moved upstream and showed a further tendency to increase as river levels declined toward the end of the summer. The 2 river stations present patterns that are not conformable with each other. Chloride concentrations were moderately high all summer for a river flowing largely off granite. Perhaps this suggests that some of the chloride in solution is anthropogenic.

Nitrate-N (Fig 11) and orthophosphate (Fig 12) concentrations were high and fluctuated irregularly during the study. Both were undoubtedly influenced greatly by agricultural practices. Sulfate concentrations in the river remained fairly constant except for sharp peaks toward the end of the June dry period (Fig 13). The pattern is only slightly reminiscent of that for chloride. In the estuary, surface water at both stations exhibited consistent increases during the June and August periods of low river flow, and at Tupperville the deeper water showed a steady increase in sulfate consistent with that of chloride. The enigmatic behavior of sulfate concentration near to the causeway is notable.

Discussion

With impoundment by the tidal dam in 1960, the Annapolis Estuary was transformed from a vertically homogeneous type of estuary with 10 m tides similar to others around the Bay of Fundy, into a highly stratified salt wedge estuary with 1 m tides. Usually a salt wedge estuary occurs when river flow is high compared with tidal flow (Perkins 1974). However, in the present instance the tidal energy in the Annapolis Basin is largely dissipated against the causeway, only surface waters entering the estuary through the sluice gates and fishway. In a sense, therefore, the Annapolis is a parody of a fjord, in which deep water in the estuary is impounded by the high sill at the mouth (Barnes 1974).

As in a fjord, restriction of inflow and outflow to surface waters results in little mixing of river and estuary water (Dyer 1972). Our results indicate that near the causeway turbulence produces some mixing such that salinity increases steadily with depth, and no halocline is present. Much of the inflowing saline water immediately descends beneath surface water because of its greater density. It would appear, to judge from the fairly high salinities recorded by Jessop (1976) and ourselves and the relatively low turbidity of deeper water, that residual or eddy currents generated by turbulence at the surface do not penetrate to the bottom.

Farther from the causeway, but within the headpond, the water was found to be highly stratified with a halocline exhibiting changes of 13 to 14‰ over 0.5 m. Such stratification is extremely stable. There is clearly little exchange taking place between the outflowing river water and the underlying salt water. As a result, there is some danger of stagnation of the lower water, and this is indicated by the oxygen saturation deficits encountered. Stratification is probably broken down periodically by wind or rain storms acting directly on the headpond. A prolonged period of hot weather, however, or an increase in oxygen demand resulting from increased organic loading of the river might well result in complete oxygen depletion of bottom waters in the estuary, an event with serious consequences for fish populations in the headpond or spawning in the lower river.

With impoundment the head of the tide, which was previously near Paradise

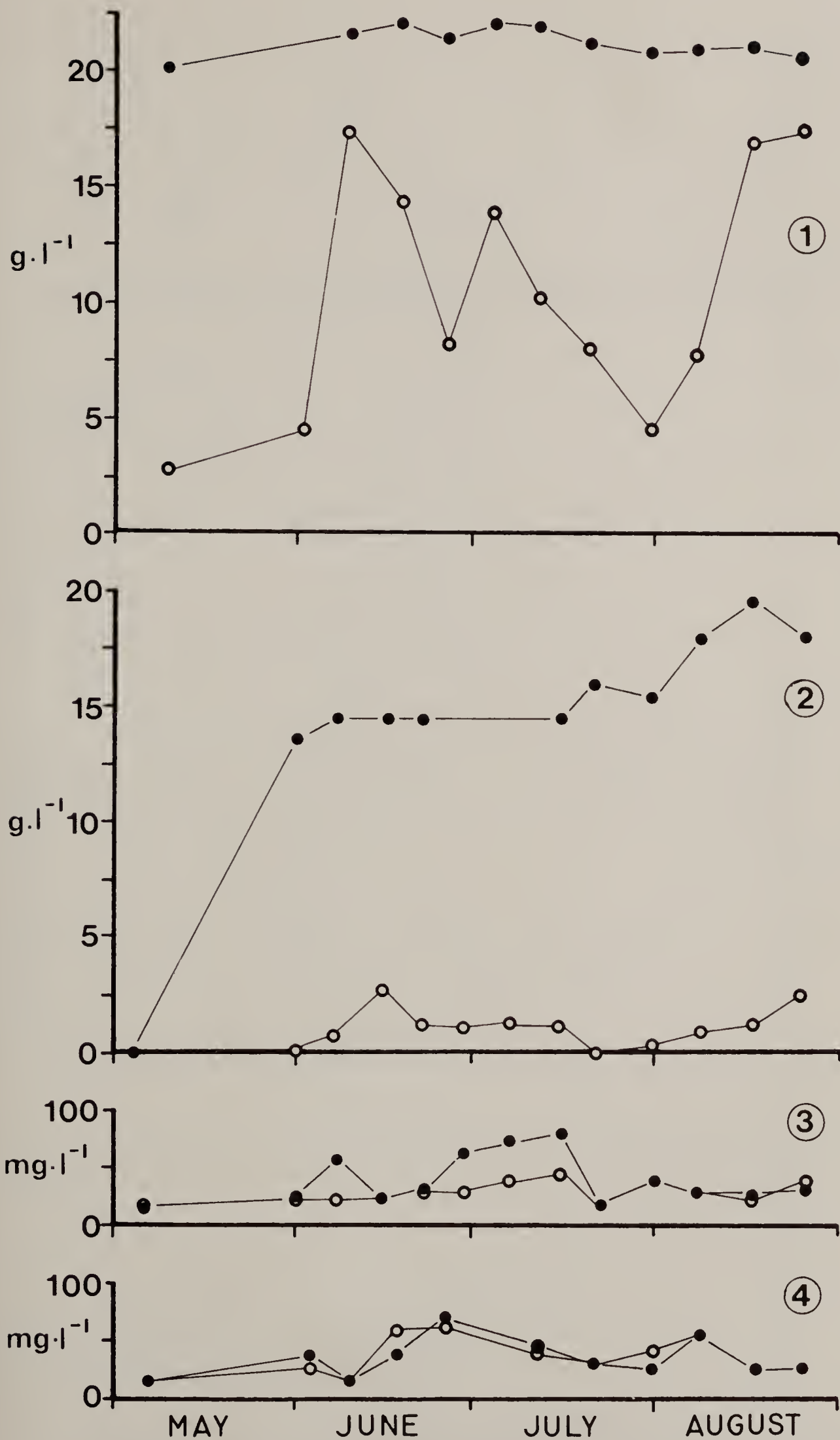


Fig 10. Chloride concentrations at stations 1-4, May-August 1976. Symbols as Fig. 6. Note difference of scale between estuary (1,2) and river (3,4) stations.

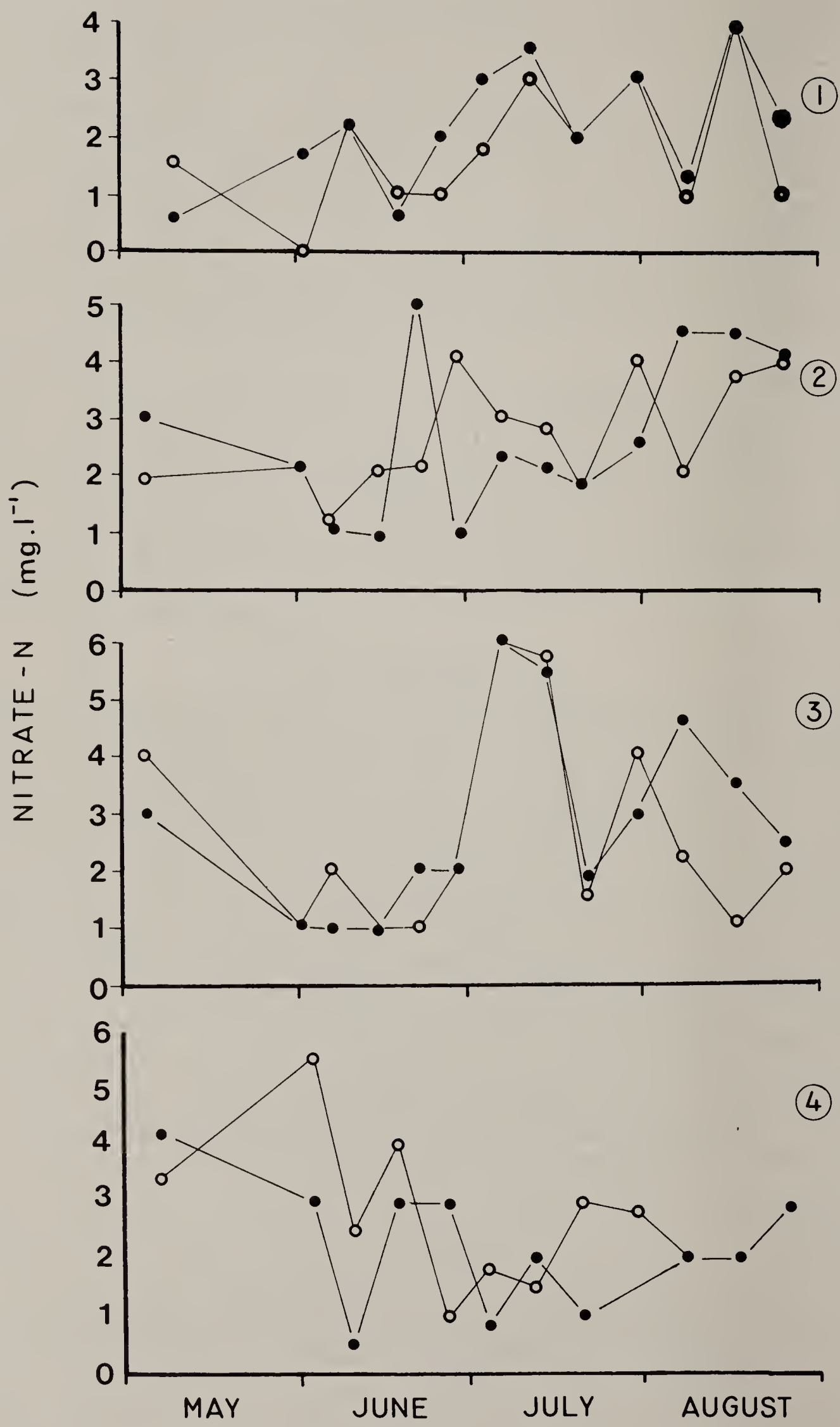


Fig 11. Nitrate—N at stations 1-4, May-August 1976. (Symbols as Fig 6.)

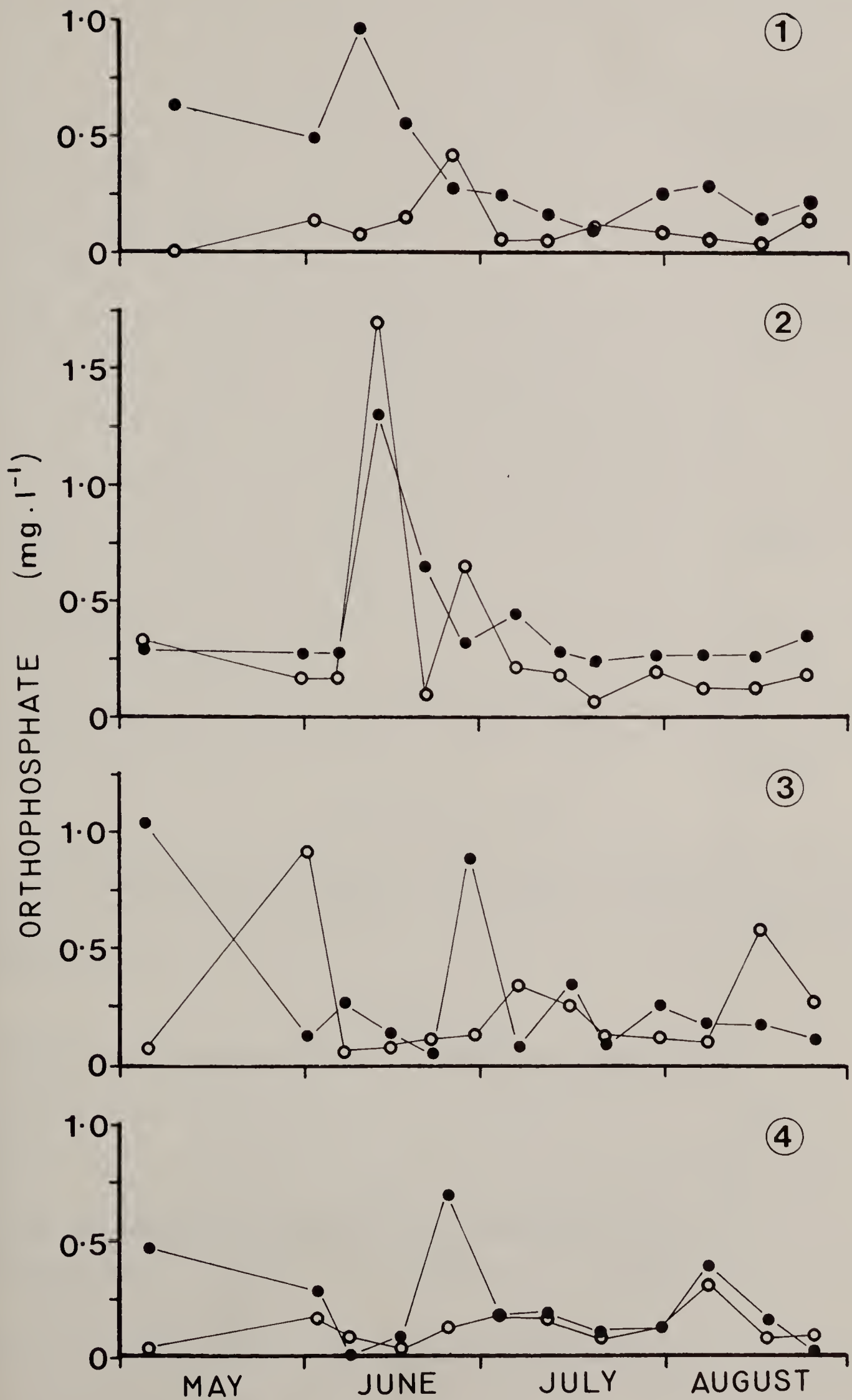


Fig 12. Orthophosphate concentrations at stations 1-4, May-August 1976 (Symbols as Fig 6.)

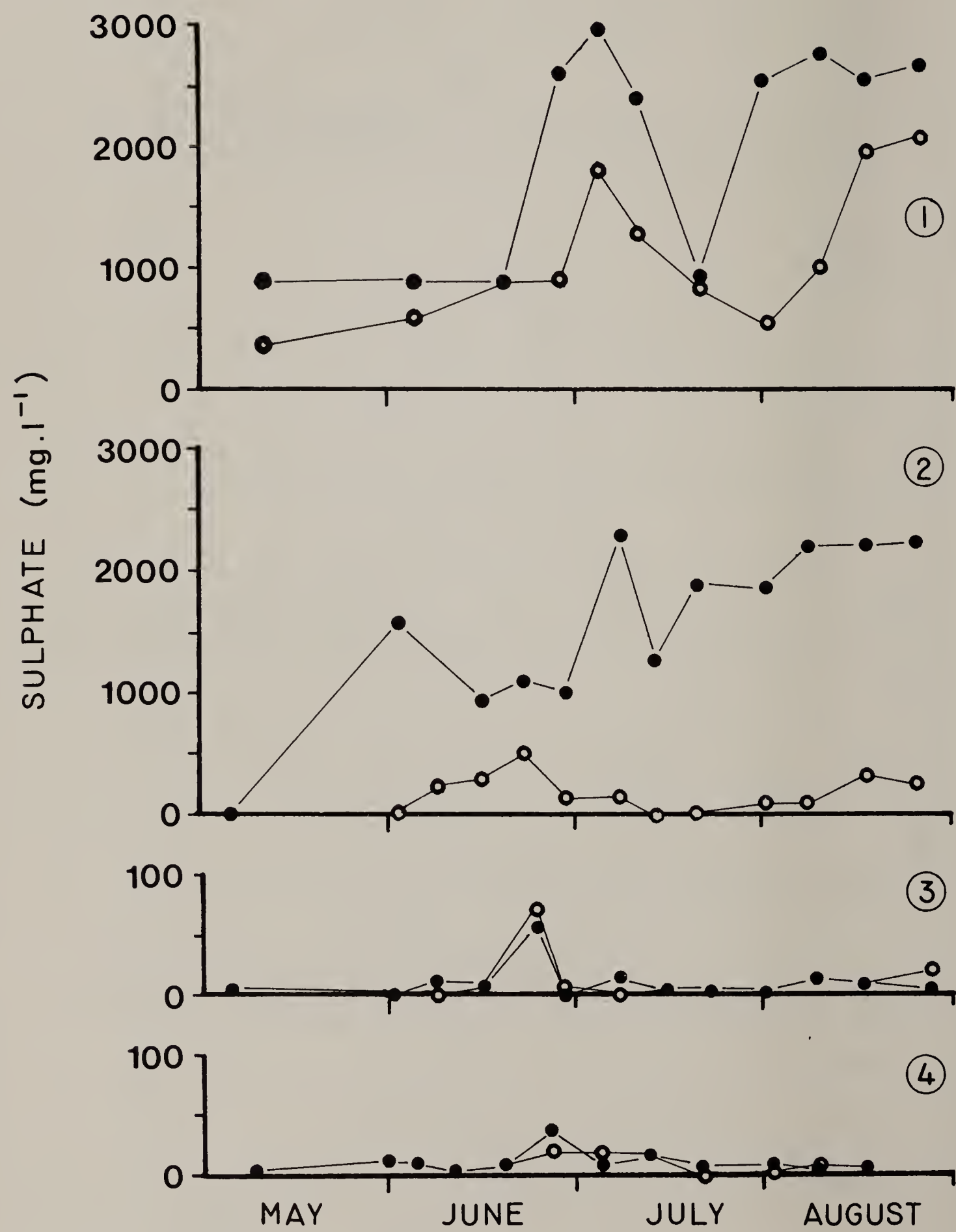


Fig 13. Sulfate concentrations at stations 1-4, May-August 1976 (Symbols as Fig 6.)

(MacDougall et al 1969), appears now to be located near Bridgetown, about 30 km above the causeway. The tip of the salt wedge oscillates some distance as a result of tidal flow, manipulation of headpond and river levels, and of intermittent water release from Paradise Reservoir into Daniel's Brook.

The river is chemically unexceptional, although our results suggest rather high levels of inorganic phosphorus and nitrate. These nutrients undoubtedly contribute to the productivity of the estuary. Although productivity of the estuary has not been studied, we noted a diverse and abundant plankton, and have documented a diverse and abundant ichthyofauna. A high productivity in the headpond is to be expected from the retention of nutrients derived from river input and dykeland drainage, and the relative clarity of the water.

The foregoing account, gleaned from our own study and those of Jessop (1976) and Jessop and Doubleday (1976) provides a basis for preliminary consideration of the effects to be expected from installation of a tidal power turbine in the Annapolis causeway. Since the turbine would withdraw water at some depth, the first consequence would be a tendency to diminish the impoundment of lower waters and allow release of these to the Annapolis Basin. Furthermore, turbulence associated with turbine operation and inflow through the sluice gates would probably help to prevent stratification over much of the headpond and decrease the danger of stagnation of bottom waters. Greater manipulation of water levels might also increase the degree of mixing between riverine and estuarine water and the generation of eddy currents throughout the headpond.

As a consequence of greater mixing and recirculation of nutrients, it is likely that primary production in the headpond would increase, although greater turbidity might restrict the photic zone.

These suggestions are clearly speculative, being based upon a study of limited scope. It is to be hoped that a more thorough investigation into the physical structure and productivity of the estuary be carried out before the Annapolis River is manipulated once again.

Acknowledgments

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LIMNOLOGY OF THE ANNAPOLIS RIVER AND ESTUARY II. FISH DISTRIBUTIONS IN THE ESTUARY, 1976 AND 1977

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Beach seine and otter trawl collections at numerous sites in the Annapolis Estuary during 1976 and 1977 produced 22 fish species. Five species were recorded only from the headpond and 3 from entirely freshwater sites, whereas the remaining species exhibited wide distributions encompassing all or most of the estuary. The wide distributions are apparently related to the highly stratified nature of the estuary which allows fish with preference for oligohaline conditions to occupy surface waters in the same stretch of the river inhabited by species preferring higher salinities. Seasonal variations in abundance and distribution are presented for the more abundant species: the alewife (*Alosa pseudoharengus*), white perch (*Morone americana*), Atlantic silverside (*Menidia menidia*), 4-spine stickleback (*Apeltes quadracus*), killifish (*Fundulus diaphanus*), and mummichog (*F. heteroclitus*).

Introduction

Despite the major role that estuarine and diadromous fishes play in the local economics of Nova Scotia, little information is available regarding the occurrence, distribution, and productivity of the species involved. In many parts of the world estuaries are rightly recognised as among the most productive of natural systems. Nourished by growth-facilitating nutrients derived from the watershed, and often considerably warmed by solar heating of intertidal mudflats, a clean estuary may represent a favorable combination of environmental conditions for those species able to tolerate or avoid variations in local salinity. On the other hand, excessive tidal amplitude, as in the Bay of Fundy, may completely nullify such advantages because of extreme turbidity and consequent restriction of phytoplankton growth, and transient patterns of sedimentation.

The Annapolis River Tidal Dam was constructed in 1960, reducing tidal range in the headpond to 1 m (Jessop 1976) compared with the range of 7 to 9 m in the Annapolis Basin itself. Fish passage is permitted through a permanently open 3 x 7 m fishway. The impoundment has resulted in extreme and relatively stable stratification in the estuary, but has also reduced markedly the high turbidity characteristic of the basin proper (Daborn et al. 1979). This combination of events has important implications for the resident migratory fishes of the area, particularly in view of the potential modification if the dam is converted for energy production by tidal power. The present study was initiated to provide a preliminary account of species composition and distribution within this presently stratified estuary.

Methods

Sampling was done primarily with a 15 m bag seine with mesh sizes of 0.6 cm in the bag and 1.3 cm on the wings. These mesh sizes select for juvenile and smaller species of fish. The seine was 2 m deep, but when drawn toward the shore was inclined to billow out under pressure and thus usually sampled only to a depth of 1.0 to 1.5 m.

During July and August 1976 a total of 62 seine collections was made at 43 sites between Annapolis Causeway (km 0) and Button Brook (km 29). These sites represented all locations in the estuary where presence of shelving beach or shallow

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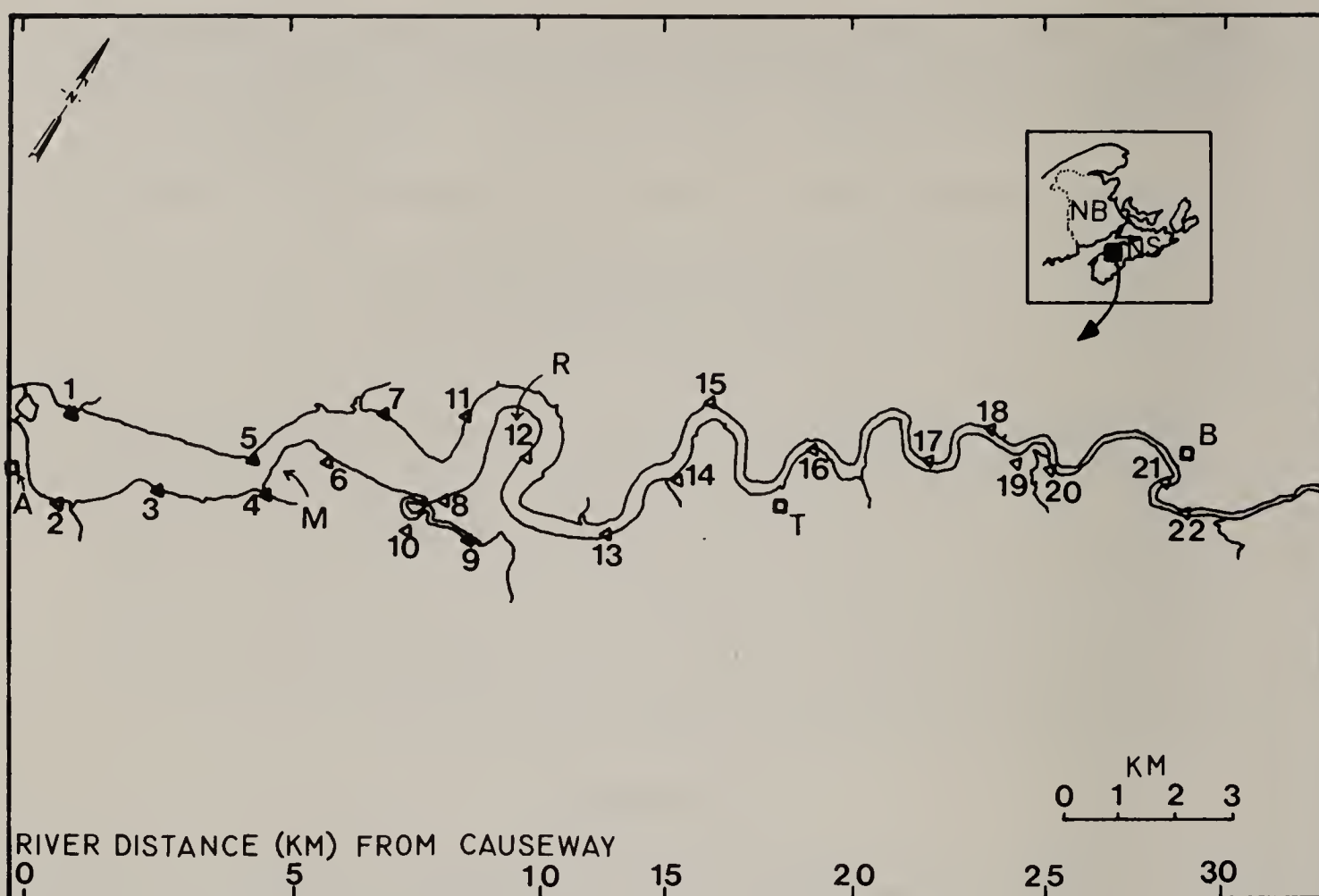


Fig 1 - The Annapolis Estuary. Inset: Maritime Provinces showing sample area. 1-22: sample station locations in 1977; A - Annapolis Royal; B - Bridgetown; M - Mochelle; R - Pré Rond; T - Tupperville.

ledges allowed the seine to be drawn to the shore close to the substrate, and thus with minimal loss of the catch. Elsewhere, slumping of river banks because of flood erosion has left almost perpendicular 2 to 5 m high banks and highly irregular substrate.

Sampling in 1977 was restricted to 22 sites (Fig 1) at intervals of 1 to 3 km from the causeway to Button Brook. From 26 May to 5 July, 11 of these sites (1, 4, 8, 9, 10, 12, 13, 15, 18, 20, 21) were sampled at intervals of 10 to 12 days. As young-of-the-year fish began to appear in samples during July, a further 10 sites were added to examine distributions more closely, and these sites were sampled at about the same intervals until 17 September. Eleven sites only were visited on 16 October. A total of 154 seine hauls was made. Captured fish were identified, counted, and released except for specimens of white perch and any fish for which identification was uncertain. These were fixed in 10% formalin and returned to the laboratory.

A site at Button Brook (No. 22, km 29) was occupied during the run of striped bass (*Morone saxatilis*) in May and June 1977. At this location a 75 m barrier net was stretched at an angle across the river and periodically used to sweep across the river in an attempt to capture striped bass. Fish collected were too numerous to count and details are not included with the seine collections described below. Information from this site regarding species occurrences, however, has been included.

Salinity and temperature were recorded with a S-C-T meter at 1 m intervals from the surface, at each sample site. Readings were made at a point about 35 m from shore, which corresponded to the maximum distance from shore sampled by the seine.

In this report, the position of each sample site (Fig 1) is identified in the text in terms of river distance (km) above the Annapolis Causeway.

Results

Species Composition

Most individuals recorded (Table I) were juveniles, except for the brook trout (*Salvelinus fontinalis*), killifish (*Fundulus diaphanus*), mummichog (*F. heteroclitus*), Atlantic silverside (*Menidia menidia*), and smelt (*Osmerus mordax*). Some juveniles could not be identified to species with complete confidence. Both the alewife (*Alosa pseudoharengus*) and shad (*A. sapidissima*) spawn in the Annapolis River, and although most of the *Alosa* spp juveniles recorded were undoubtedly alewives, some shad were probably present. Similarly, in 1976 the killifish and mummichog were not separated, although collections undoubtedly included both species.

Other species known to be present in the estuary, but not always identified with certainty in our collections, are the windowpane (*Scophthalmus aquosus*) and 3-spine stickleback (*Gasterosteus aculeatus*). Four little skate (*Raja erinacea*) were collected by otter trawl in 1976 (Williams 1977).

Species Distributions

The Annapolis is a highly stratified estuary, a consequence of construction of the Annapolis Causeway and the resultant restriction of tidal influences (Jessop 1976; Daborn et al. 1979). The highly stable stratification extends a considerable distance upstream. The exact location of the salt wedge tip varies according to river flow

Table I. Species collected by bag seine in the Annapolis estuary, 1976 and 1977.

Name	No. Collected		Range in 1977	
	1976	1977	Stations ¹	km ²
<i>Alosa</i> spp (alewife and shad)	7,147	9,134	1-21	0-28
<i>Menidia menidia</i> (Atlantic silverside)	1,496	11,783	1-17	0-22
<i>Osmerus mordax</i> (rainbow smelt)	3	200	1-16	0-18
<i>Anguilla rostrata</i> (eel)	121	421	1-21	0-28
<i>Morone americana</i> (white perch)	118	411	3-22	2-29
<i>Morone saxatilis</i> (striped bass)	1	2	1-22	0-29
<i>Fundulus diaphanus</i> (banded killifish)	(217) ³	297	1-21	0-28
<i>Fundulus heteroclitus</i> (mummichog)		64	1-19	0-24
<i>Catostomus commersonii</i> (white sucker)	59	41	15-21	16-28
<i>Semotilus atromaculatus</i> (creek chub)	10	6	17-21	22-28
<i>Apeltes quadracus</i> (4-spine stickleback) ⁴	835	952	1-21	0-28
<i>Pungitius pungitius</i> (9-spine stickleback)		33	1-21	0-28
<i>Pseudopleuronectes americanus</i> (winter flounder) ⁵	31	60	1-21	0-28
<i>Pollachius virens</i> (pollock)	10			
<i>Tautoglabrus adspersus</i> (cunner)		9	1	0
<i>Microgadus tomcod</i> (tomcod)		3	1-5	0-5
<i>Syngnathus fuscus</i> (pipefish)	3	4	1-5	0-5
<i>Salvelinus fontinalis</i> (brook trout)		1	20	25
TOTALS	10,051	23,427		

1 Sample station numbers at which species collected in 1977
2 Range of river in km above causeway
3 Distinction between species of *Fundulus* not made in 1976
4 Records might include juveniles of 3-spine stickleback, *Gasterosteus aculeatus*
5 Records might include juveniles of the windowpane, *Scophthalmus aquosus*.

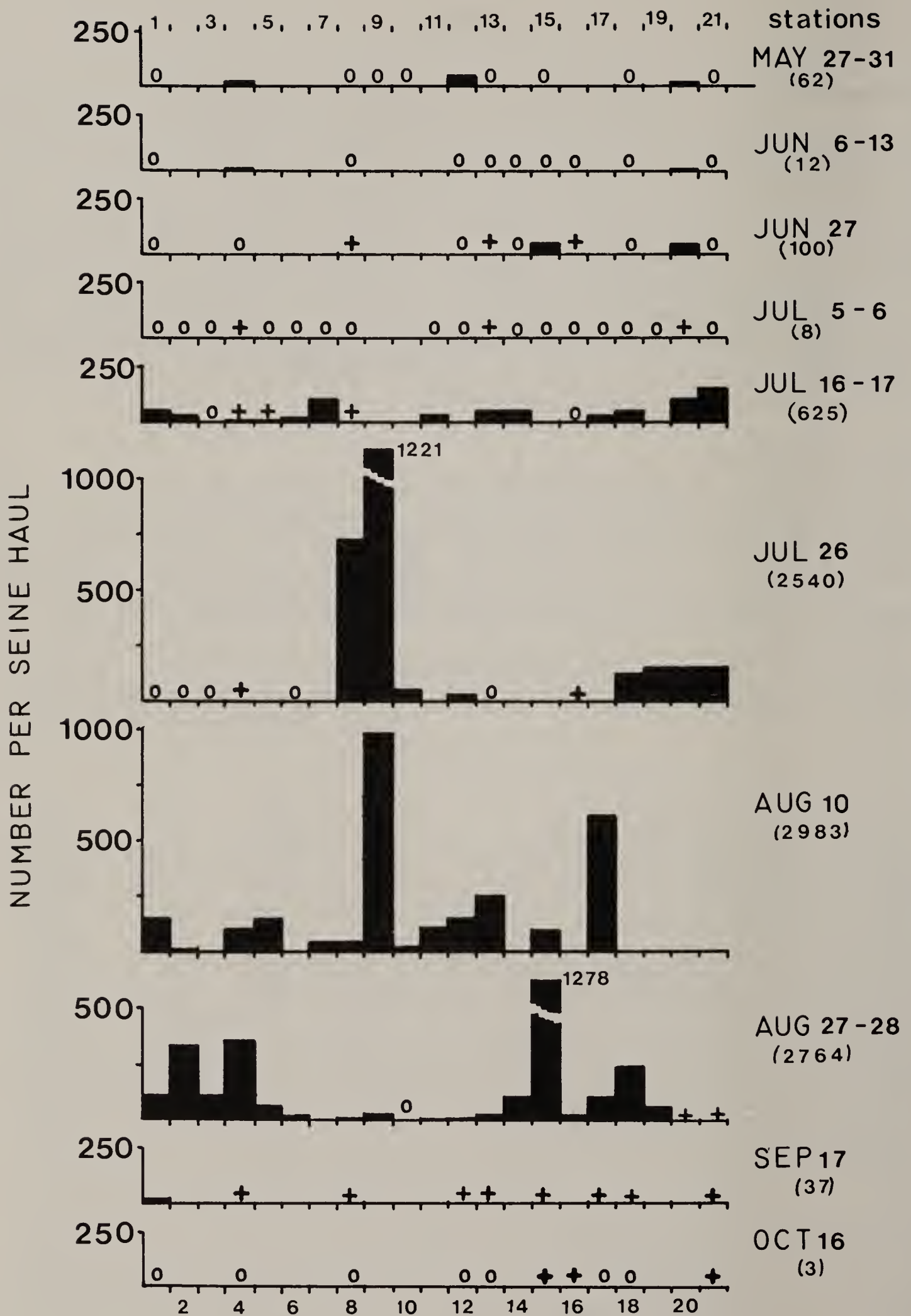


Fig 2 - Seine collections of alewife and shad (*Alosa* spp) in 1977.

- o: sample taken but species not captured;
- +: species present in low numbers;
- (): total numbers collected;
- 1-21: sample station numbers.

conditions and tidal phase, oscillating between Messenger Brook (km 22) and Bridgetown (km 28). Wind-induced turbulence is much diminished above Mochelle (km 5) where the river narrows abruptly and above which it meanders extensively. Thus the interface between fresh and salt water becomes progressively more acute upstream. Details of the physical structure of the river during 1976 are provided elsewhere (Daborn et al. 1979).

Of the 22 species recorded in the estuary in the 2 years, a few were only collected in the headpond region (sites 1-5). These include the tomcod, cunner, pollock, pipefish, and little skate (Table I). Winter flounder juveniles were captured up to Pré Rond East, about 10 km above the causeway. A 2 m deep bag seine is clearly a highly unsatisfactory sampling device for large, deep waters as in the headpond, and thus no comments can be made regarding the prevalence or distribution of these species. Three other species were collected only at the more upstream stations, where the salt wedge failed to penetrate or was represented by only a shallow layer on the bottom. These species were the creek chub, white sucker, and brook trout. All other species were recorded, or known to occur, throughout the sample areas, and thus exhibited completely over-lapping distributions.

Five species exhibited extensive migratory movement upstream during the sampling season. The catadromous eel was present throughout the estuary from May until September, but particularly large numbers of elvers were collected in early and mid-July (244 of 421 captured), suggesting an upstream movement of young entering the river from the sea. A decline in captures during September and October indicates that this species moves completely into freshwater in the autumn.

At the end of May and in early June, large numbers of alewives, white perch, a few shad, and striped bass were captured in the barrier net set up at Button Brook (km 29). Adult alewives and white perch were also caught in the bag seine at this time. All 4 species spawn in freshwater regions of the Annapolis River ($> \text{km } 29$), the striped bass just above the farthest extension of the salt wedge (Williams 1977) while the shad, white perch and alewives penetrate progressively farther upstream.

Both striped bass and shad lay pelagic eggs that float downstream and hatch in or near salt water. Few juvenile striped bass have been collected during this study, despite extensive sampling for them, but some of the unidentified *Alosa* spp juveniles captured by seine at lower stations during July (Fig 2) were probably larval shad. Details of spawning times for striped bass and shad are available elsewhere (Williams 1977). The alewives and white perch, on the other hand, spawn in June, laying demersal, slightly adhesive eggs that complete development in freshwater. Young-of-the-year alewives were first encountered on 16 July, primarily at the more upstream stations ($> 10 \text{ km}$), but subsequently were collected throughout the river. During July and August they were particularly abundant in samples near Evans Brook (km 8). By the autumn, few young alewives were captured at any sites, although individuals were caught throughout the river, and we presume that the majority had moved downstream into the headpond or beyond.

Young-of-the-year white perch were first encountered in mid-July, primarily at Gesner Brook (km 16), but also in shallow waters of the headpond (Fig 3). In late summer and autumn they were caught over much of the estuary and were still present in small numbers when the last samples were taken in mid-October. Examination of scales suggests that this population does not run out to sea and thus we presume that adults and young overwinter in the headpond or Annapolis Basin.

The remaining species can be considered to be true residents of the estuary. The 4-spine stickleback, for example, was captured at points over the whole estuary, although largest numbers were encountered along the headpond shoreline (Fig 4). Adults in spawning condition were caught on 6 June, and young-of-the-year first appeared in the 5 to 6 July samples. A similar pattern of distribution in space and time of breeding was observed for the 9-spine stickleback, but total catch of this species was small.

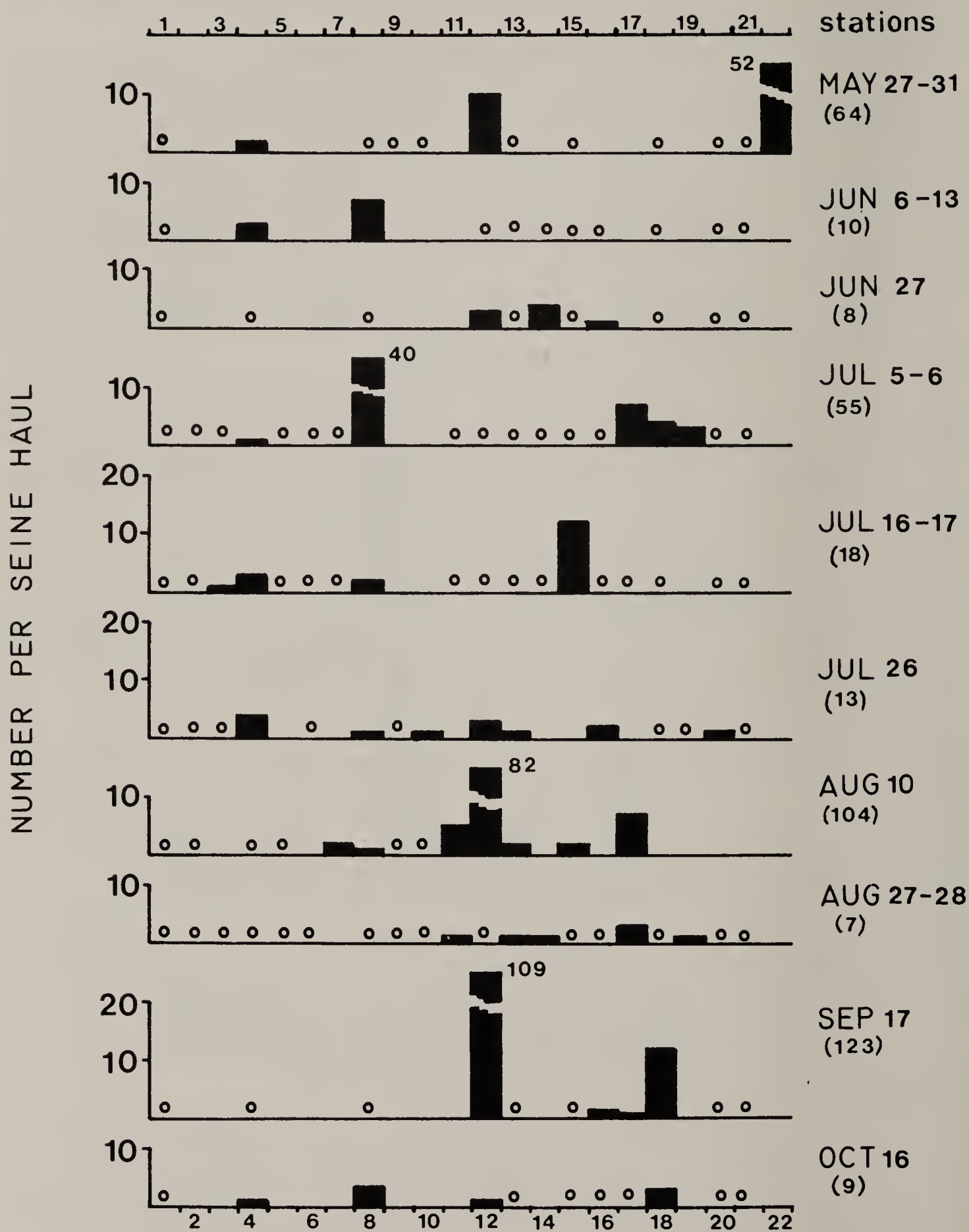


Fig 3 - Seine collections of white perch (*Morone americana*) in 1977. Symbols as Fig 2.

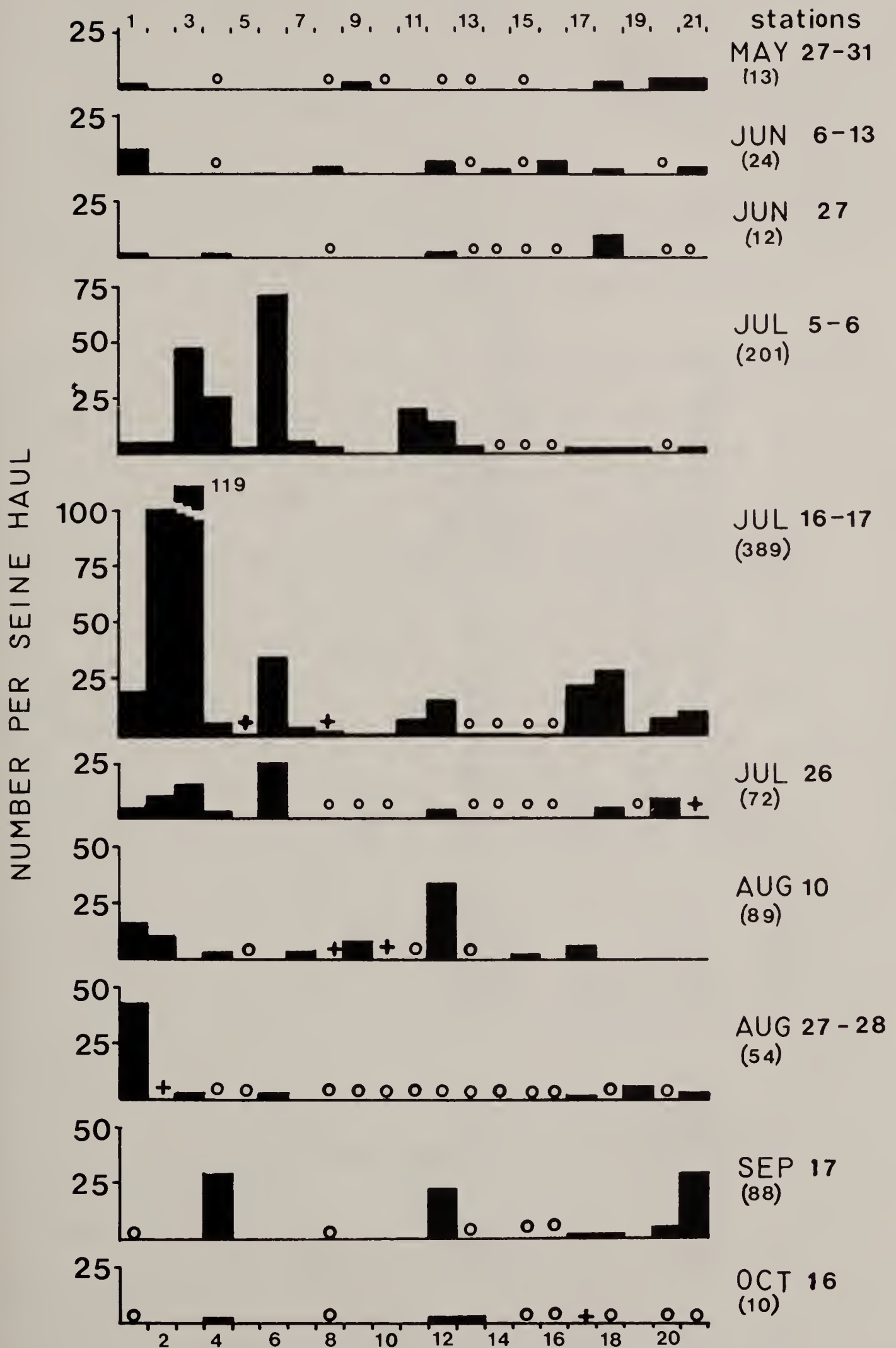


Fig 4 - Seine collections of 4-spine stickleback (*Apeltes quadracus*) in 1977. Symbols as Fig 2.

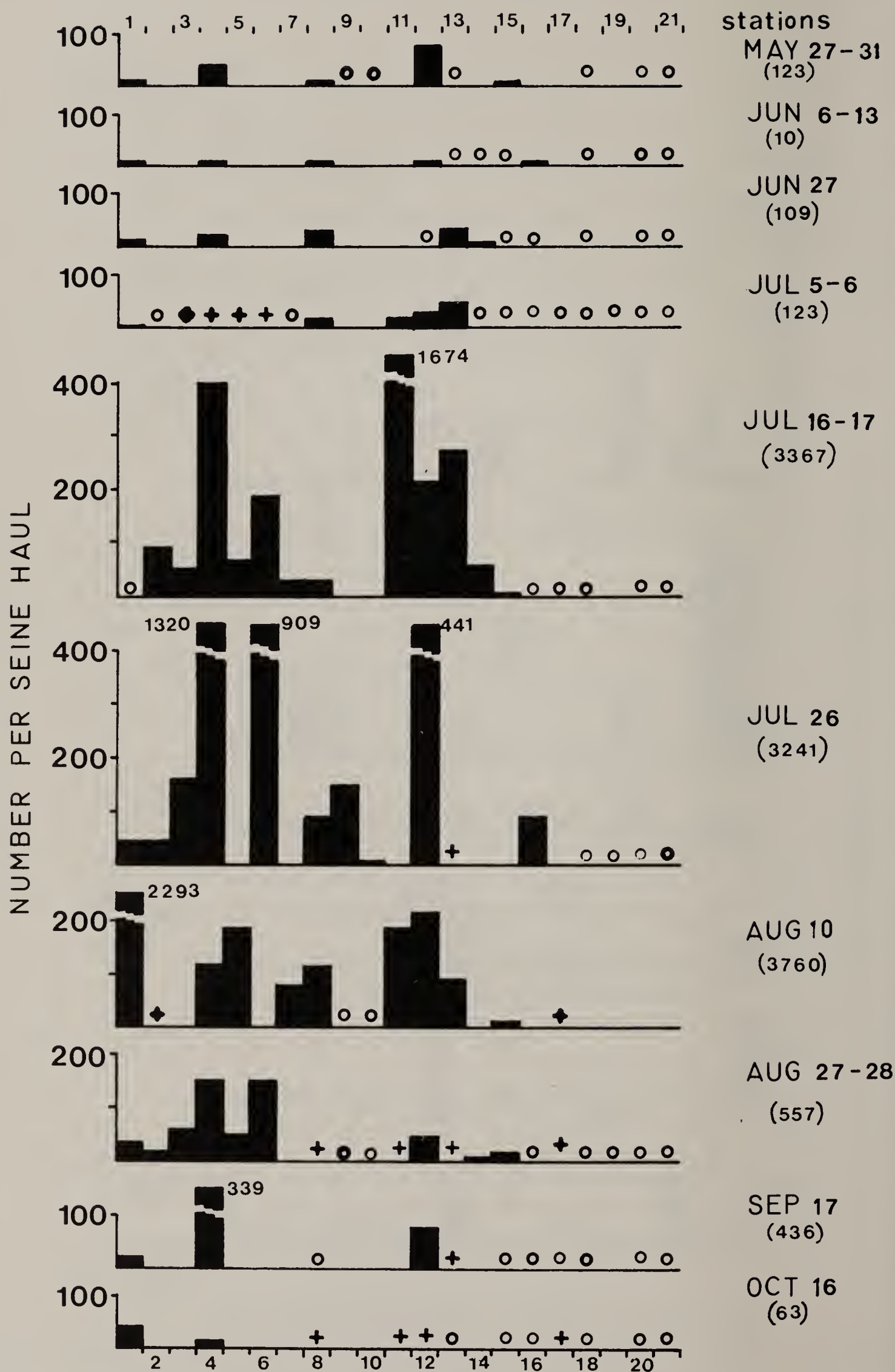


Fig 5 - Seine collections of Atlantic silversides (*Menidia menidia*) in 1977: Symbols as Fig 2.

One of the most important of resident species is undoubtedly the Atlantic silverside. As with the sticklebacks, it was encountered over much of the estuary (km 0-22), with young-of-the-year occurring in large numbers in the collections of July and August (Fig 5). In the October samples, the catch had diminished substantially, but a few silversides were caught as far upstream as Messenger Brook (km 22). Adults in spawning condition were seen on 22 June and the first young-of-the-year were caught on 5 July.

The 2 species of *Fundulus* were encountered together over most of the estuary (Fig 6), but young were particularly frequent in the middle estuary between Pré Rond (km 9) and Upper Granville (km 23). Both species breed about the end of June, and young first appeared in samples in mid-July.

Discussion

Inferences regarding the distribution of species in a large estuary, based upon collections with a 2 m deep bag seine are clearly hazardous. The Annapolis estuary is a difficult river to sample in any manner. Uneven bottom configuration resulting from river bank slumping and the presence of glacial erratic boulders precludes use of an otter trawl except in the headpond itself. There are few places in which the bottom shelves gradually, more often the banks are eroded to the perpendicular. Furthermore, much of the estuary is considerably deeper than the 1 to 1.5 m effectively sampled by our seine and thus escapement of more active fish is inevitable. Demersal fish cannot be effectively sampled except in very shallow upstream regions.

The vagaries of seining may well be the reason for great variation in numbers of a species captured at particular sites. Pré Rond (station 12) and Evans Brook (stations 8 and 9) which were particularly prolific sites, for example, may simply have been more suitable for operation of a bag seine. Alternatively, the large catches of alewives and silversides at various localities might merely reflect the chance enclosure of schools of these species. Where the greatest catches varied from one site to another on successive sampling dates, as with the alewife (Fig 2), we presume that sampling variability was primarily the result of close schooling behavior.

What remains most striking is the considerable range over which resident species, particularly, were encountered. Most truly estuarine species are euryhaline, compared with strictly freshwater or marine species, and thus might be expected to occupy a considerable stretch of the estuary. In well-mixed estuaries, however, there is usually a more-or-less distinct longitudinal succession of species reflecting the salinity gradient from the mouth of the estuary into the river (Cronin & Mansueti 1971; Perkins 1974). Indeed, salinity is one of the primary environmental factors influencing estuarine fish distributions (eg. McErlean et al. 1973; Hoff & Ibara 1977). In the Annapolis River, however, presence of the salt wedge > 20 km above the causeway allows species with high salinity preferences to occupy bottom waters over the range. Conversely, species preferring oligohaline waters can occupy surface waters over the same distance. At any given location, therefore, sampling to the full depth of the estuary should produce individuals representative of almost the whole estuarine ichthyofauna, rather than a limited subset of that fauna determined by salinity preferences as in well-mixed estuaries.

The present study is the first of its kind on the Annapolis River. It is interesting to note that sampling by both seine and otter trawl (Williams 1977) over 2 years produced a total of 22 species. Although a few might have been missed, particularly in the headpond, the Annapolis River ichthyofauna is clearly much less diverse than that of estuaries farther south. A similar study in a New England estuary, for example, recorded no less than 54 species (Hoff & Ibara 1977), whereas otter trawl sampling in Narragansett Bay collected 80 species (Jeffries & Johnson 1974).

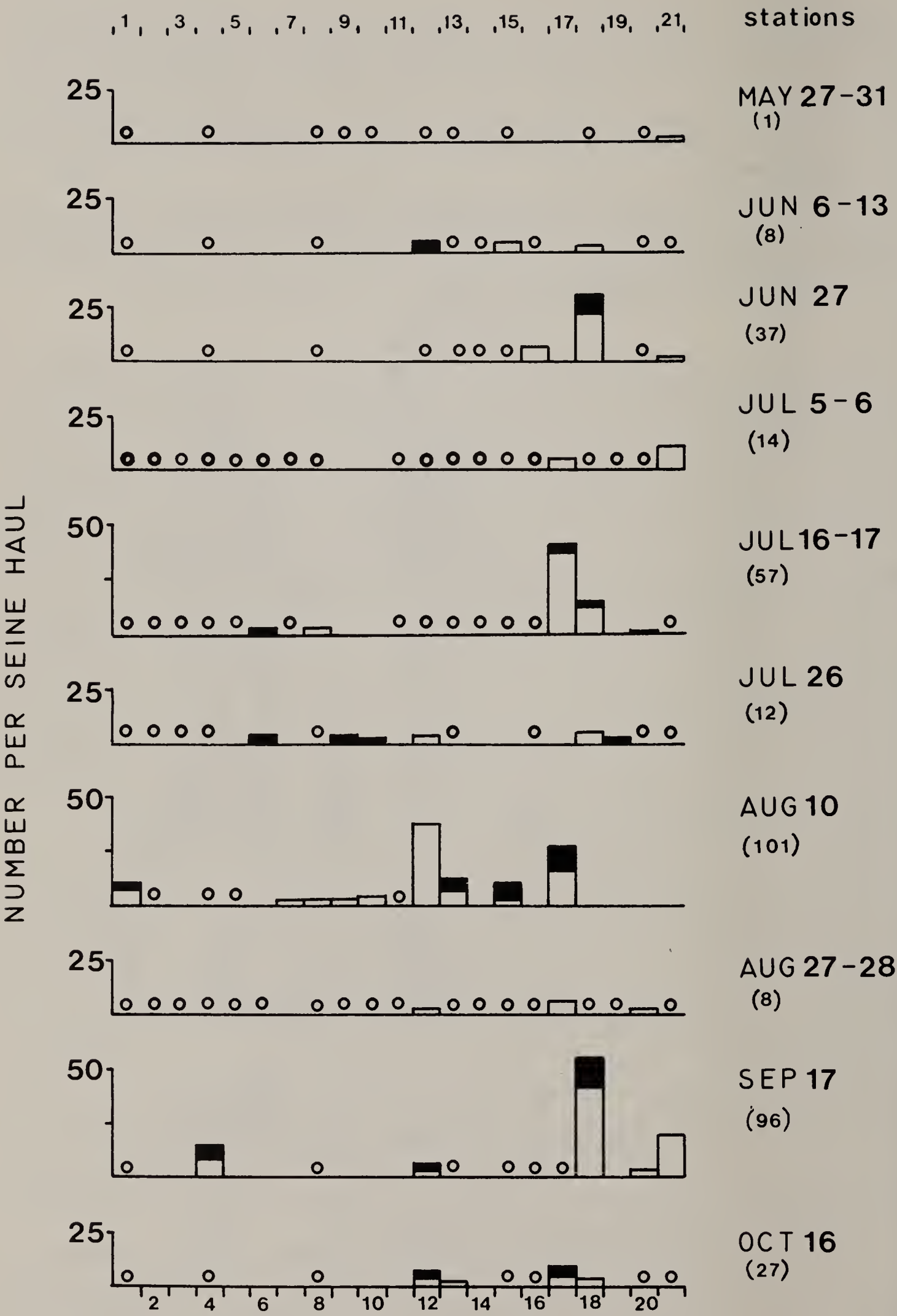


Fig 6 - Seine collections of banded killifish (*Fundulus diaphanus*) and mummichog (*F. heteroclitus*) in 1977. Open bars: killifish; closed bars: mummichog. Other symbols as Fig 2.

Impoundment of the Annapolis River to control tidal flooding of reclaimed land has resulted in formation of a large and apparently fairly productive stratified headpond. A more complete study of fish populations and productivity of the headpond is desirable and should be done before further modifications to the causeway are made.

Acknowledgments

This study was supported partly by contract OSU5-0163 from the Resource Development Branch, Fisheries and Marine Service, Environment Canada, and partly by National Research Council of Canada operating grant A9679 to G.R. Daborn. We acknowledge with gratitude the valuable advice, assistance and loan of equipment by Brian Jessop, Fisheries and Marine Service, Environment Canada. We are also grateful to many of our colleagues who have been involved in various aspects of this research, particularly J.S. Boates, S. Franey, O. Krepinski, R. Mackenzie, C. Pennachetti, M. Roberge, P.S. Smith, and K. Strong.

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MITES, TICKS, FLEAS, AND LICE IN THE NOVA SCOTIA MUSEUM AND ACADIA UNIVERSITY MUSEUM COLLECTIONS

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A list of 111 species of ectoparasites with host data, based on 1750 samples in the Acadia University Museum and Nova Scotia Museum collections, is presented. The material was determined by the staff of the Biosystematics Research Institute, Ottawa.

Introduction

In recent years, a substantial collection of ectoparasites has accumulated at the Nova Scotia Museum and in the Acadia University Museum. Ectoparasites were collected as a part of routine processing of animals caught during a small-mammal survey conducted by Nova Scotia Museum staff in 1971. The Acadia University collections resulted largely from tick surveys conducted by R. E. Yescott and A. M. Martell, working under the direction of D. Dodds, in the Tobeatic Game Sanctuary in 1965 and by Alan Campbell and David Harris in the Hibernia Wildlife Management Area, Queens County, in 1975. The objective of this paper is to make these records generally available.

Previous records of ectoparasites of birds and mammals in Nova Scotia are almost entirely lacking. Holland's Siphonaptera of Canada (1949), for example, contains but a single record of a flea from this province. To my certain knowledge, there are no previously published Nova Scotian records of lice, mites, or ticks apart from those which are of economic significance. Seventy-three species of mites, 8 of ticks, 21 of fleas, and 9 of lice are recorded in the present paper.

Altogether, 1750 samples have been identified by the staff of the Biosystematics Research Institute in Ottawa, whose assistance is gratefully acknowledged. G. P. Holland identified the fleas, K. W. Wu and E. E. Lindquist the mites, and J. E. H. Martin the ticks and lice. Ticks recorded from Hibernia were determined by Alan Campbell. All of the material determined in Ottawa is mounted on microscope slides which are deposited in the collections of the 2 museums.

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Systematic ListClass **Arachnida**Subclass **Acarina**Order **Parasitiformes**Suborder **Mesostigmata****Ologamasidae***Euryparasitus* sp.Whale Cove, Digby Co., ex *Blarina brevicauda*Tobeatic Game Sanctuary, ex *Sorex cinereus*; *Blarina brevicauda*; *Condylura cristata*; *Microtus pennsylvanicus*; *Clethrionomys gapperi*;Kelly's Mountain, near Englishtown, Victoria Co., ex *Peromyscus maniculatus*;
*Napaeozapus insignis*Tomahawk Lake, Halifax Co., ex *Napaeozapus insignis**Cyrtolaelaps* sp.Whale Cove, Digby Co., ex *Blarina brevicauda*Tobeatic Game Sanctuary, ex *Sorex cinereus*; *Blarina brevicauda*; *Clethrionomys gapperi*; *Peromyscus leucopus***Parholaspidae***Neparholaspis* sp.Tobeatic Game Sanctuary, ex *Peromyscus maniculatus***Parasitidae***Gamasodes* sp.Tobeatic Game Sanctuary, ex *Peromyscus leucopus**Parasitus* sp.Whale Cove, Digby Co., ex *Peromyscus leucopus*Tobeatic Game Sanctuary, ex *Blarina brevicauda*; *Clethrionomys gapperi*,
*Peromyscus leucopus**Pergamasus* sp.Whale Cove, Digby Co., ex *Blarina brevicauda*Tobeatic Game Sanctuary, ex *Blarina brevicauda*; *Microtus pennsylvanicus*;
Peromyscus maniculatus; *Peromyscus leucopus*Sherbrooke, Guysborough Co., ex *Zapus hudsonius**Poecilochirus* sp.Tobeatic Game Sanctuary, ex *Sorex cinereus*; *Synaptomys cooperi*; *Clethrionomys gapperi*; *Microtus pennsylvanicus*; *Peromyscus leucopus*

Bridgewater, Lunenburg Co., in pitfall trap

Waverley, Halifax Co., in pitfall trap

Boulderwood, Halifax Co., ex carrion beetle (*Nicrophorus* sp.)Dartmouth, Halifax Co., ex carrion beetle (*Nicrophorus* sp.)

Genus undet. (Parasitidae)

Tobeatic Game Sanctuary, ex *Microtus pennsylvanicus*; *Peromyscus leucopus***Ascidae***Cheiroseius* sp.Tobeatic Game Sanctuary, ex *Peromyscus leucopus*

Neojordensia sp.

Tobeatic Game Sanctuary, ex *Sorex palustris*; *Microtus pennsylvanicus*

Lasioseius confusus Evans

Tobeatic Game Sanctuary, ex *Microtus pennsylvanicus*

Proctolaelaps hypudaei (Ouds.)

Tobeatic Game Sanctuary, ex *Sorex palustris*; *Blarina brevicauda*; *Synaptomys cooperi*; *Microtus pennsylvanicus*, *Clethrionomys gapperi*; *Peromyscus leucopus*

Macrochelidae

Macrocheles sp.

Tobeatic Game Sanctuary, ex *Microtus pennsylvanicus*; *Clethrionomys gapperi*

Uropodidae

Genus undet. (Uropodidae)

Tobeatic Game Sanctuary, ex *Clethrionomys gapperi*

Dermanyssidae

Dermanyssus hirundinis (Hermann)

Halifax, Halifax Co., ex swallow nest

Ornithonyssus sylviarum (C. & F.)

Halifax, Halifax Co., ex *Icteria virens*

Sable Island, ex dead *Passerculus sandwichensis princeps*

Macronyssidae

Macronyssus crosbyi (Ewing and Stover)

Tobeatic Game Sanctuary, ex *Myotis* sp.; *Clethrionomys gapperi*

Spinturnicidae

Spinturnix sp.

Tobeatic Game Sanctuary, ex *Myotis* sp.

Laelapidae

Androlaelaps glasgowi (Ewing)

Oxford, Cumberland Co., ex *Clethrionomys gapperi*

Androlaelaps sp. (1)

Tobeatic Game Sanctuary, ex *Blarina brevicauda*; *Zapus hudsonius*

Tomahawk Lake, Halifax Co., ex *Napaeozapus insignis*

Oxford, Cumberland Co., ex *Peromyscus maniculatus*

Sherbrooke, Guysborough Co., ex *Zapus hudsonius*

Kelly's Mountain, near Englishtown, Victoria Co., ex *Napaeozapus insignis*

Androlaelaps sp. (2)

Salt Springs, Pictou Co., ex *Marmota monax*

Androlaelaps sp. (3)

Tobeatic Game Sanctuary, ex *Blarina brevicauda*; *Microtus pennsylvanicus*;

Clethrionomys gapperi; *Peromyscus maniculatus*; *Peromyscus leucopus*

South Brookfield, Queens Co., ex *Clethrionomys gapperi*

Oxford, Cumberland Co., ex *Microtus pennsylvanicus*

Sherbrooke, Guysborough Co., ex *Peromyscus leucopus*; *Zapus hudsonius*

Hypoaspis sp. (1)Tobeatic Game Sanctuary, ex *Peromyscus leucopus**Hypoaspis* sp. (2)Tobeatic Game Sanctuary, ex *Peromyscus leucopus**Laelaspis* sp.Tobeatic Game Sanctuary, ex *Zapus hudsonius**Ololaelaps* sp.Tobeatic Game Sanctuary, ex *Microtus pennsylvanicus*; *Zapus hudsonius*
Sherbrooke, Guysborough Co., ex *Zapus hudsonius**Hyperlaelaps* sp.Tobeatic Game Sanctuary, ex *Microtus pennsylvanicus*; *Clethrionomys gapperi*;
*Zapus hudsonius*Tomahawk Lake, Halifax Co., ex *Microtus pennsylvanicus*Oxford, Cumberland Co., ex *Microtus pennsylvanicus*; *Zapus hudsonius*Sherbrooke, Guysborough Co., ex *Microtus pennsylvanicus**Laelaps* sp.Tobeatic Game Sanctuary, ex *Microtus pennsylvanicus*; *Clethrionomys gapperi*
Petpeswick, Halifax Co., ex *Microtus pennsylvanicus**Ondatra laelaps multispinosa* (Banks)Tobeatic Game Sanctuary, ex *Ondatra zibethicus***Haemogamasidae***Eulaelaps stabularis* (Koch)Whale Cove, Digby Co., ex *Blarina brevicauda*Tobeatic Game Sanctuary, ex *Sorex cinereus*; *Blarina brevicauda*; *Microtus pennsylvanicus*; *Clethrionomys gapperi*; *Peromyscus leucopus*Simpson Lake, Colchester Co., ex *Clethrionomys gapperi*Kelly's Mountain, near Englishtown, Victoria Co., ex *Blarina brevicauda***Hirstionyssidae***Hirstionyssus* sp. nr *isabellinus* (Ouds.)Tobeatic Game Sanctuary, ex *Blarina brevicauda*; *Condylura cristata*; *Microtus pennsylvanicus*; *Clethrionomys gapperi*; *Peromyscus maniculatus*; *Procyon lotor*Simpson Lake, Colchester Co., ex *Clethrionomys gapperi**Hirstionyssus talpae* ZenskayaTobeatic Game Sanctuary, ex *Blarina brevicauda**Hirstionyssus* sp. (?*blarinae* Herrin)Tobeatic Game Sanctuary, ex *Microtus pennsylvanicus***Haemogamasidae***Haemogamasus* sp. (1)Wolfville, Kings Co., ex *Glaucmys sabrinus**Haemogamasus* sp. (2) (?*ambulans* Thorell)Tobeatic Game Sanctuary, ex *Sorex palustris*; *Blarina brevicauda*; *Microtus pennsylvanicus*; *Clethrionomys gapperi*; *Peromyscus leucopus*Lower Sackville, Halifax Co., ex *Peromyscus leucopus*Simpson Lake, Colchester Co., ex *Clethrionomys gapperi*; *Napaeozapus insignis*Sherbrooke, Guysborough Co., ex *Microtus pennsylvanicus*

Kelly's Mountain, near Englishtown, Victoria Co., ex *Blarina brevicauda*;
Napaeozapus insignis

Haemogamasus sp. (3) (?*liponyssoides* Ewing)

Tobeatic Game Sanctuary, ex *Sorex cinereus*; *Sorex palustris*; *Blarina brevicauda*;
Condylura cristata; *Microtus pennsylvanicus*, *Clethrionomys gapperi*; *Peromyscus leucopus*

Haemogamasus alaskensis Ewing

Oxford, Cumberland Co., ex *Clethrionomys gapperi*

Order Parasitiformes

Suborder Ixodides

Ixodidae

Dermacentor variabilis (Say)

Tobeatic Game Sanctuary, adults ex *Procyon lotor*; *Erethizon dorsatum*. Juveniles
ex *Microtus pennsylvanicus*; *Synaptomys cooperi*; *Clethrionomys gapperi*;
Peromyscus leucopus; *Peromyscus maniculatus*; *Zapus hudsonius*; *Ondatra*
zibethicus; *Procyon lotor*; *Erethizon dorsatum*

Jordan Falls, Shelburne Co., from vegetation

Shelburne, Shelburne Co., from clothing

Liverpool, Queens Co., in parcel packing

Lake Kejimikujik, Queens Co., from clothing and vegetation

Boarback Lake, Digby Co., from clothing

Hibernia Wildlife Management Area, adults ex *Procyon lotor*; *Erethizon dorsatum*;
Ursus americanus; *Tamias striatus*. Juveniles ex *Clethrionomys gapperi*; *Microtus pennsylvanicus*;
Peromyscus leucopus; *Zapus hudsonius*; *Tamias striatus*;
Napaeozapus insignis; *Lepus americanus*

Dermacentor albipictus (Packard)

Annapolis Co., ex *Odocoileus virginianus*

Blue Mountain, Pictou Co., ex *Alces alces*

Haemaphysalis leporis-palustris (Packard)

Tobeatic Game Sanctuary, ex *Microtus pennsylvanicus*; *Tamiasciurus hudsonicus*;
Lepus americanus; *Canachites canadensis*; *Bonasa umbellus*; *Turdus migratorius*;
Hylocichla ustulata

Halifax, Halifax Co., ex *Lepus americanus*

Brookfield, Colchester Co., ex *Lepus americanus*

Top of Kelly's Mountain, near Englishtown, Victoria Co., ex *Junco hyemalis*

Hibernia Wildlife Management Area, juveniles ex *Lepus americanus*

Rhipicephalus sanguineus (Latreille)

Armdale, Halifax Co., ex *Canis familiaris*

Windsor, Hants Co., ex *Canis familiaris*

Ixodes angustus Neumann

Tobeatic Game Sanctuary, ex *Blarina brevicauda*; *Microtus pennsylvanicus*;
Clethrionomys gapperi

Digby, Digby Co., ex *Blarina brevicauda*

South Brookfield, Queens Co., ex *Napaeozapus insignis*

Sherbrooke, Guysborough Co., ex *Sorex fumeus*; *Clethrionomys gapperi*;
Peromyscus leucopus

Oxford, Cumberland Co., ex *Microtus pennsylvanicus*

Hibernia Wildlife Management Area, ex *Microtus pennsylvanicus*; *Clethrionomys gapperi*

Ixodes marxi BanksWolfville, Kings Co., ex *Glaucomys sabrinus*Hibernia Wildlife Management Area, ex *Tamiasciurus hudsonicus**Ixodes cookei* PackardTobeatic Game Sanctuary, ex *Erethizon dorsatum*; *Procyon lotor*Wolfville, Kings Co., ex *Mustela erminea**Ixodes muris* Bishopp & SmithTobeatic Game Sanctuary, ex *Sorex cinereus*Whale Cove, Digby Co., ex *Sorex cinereus*Kempt, Queens Co., ex *Zapus hudsonius*Sherbrooke, Guysborough Co., ex *Napaeozapus insignis*Hibernia Wildlife Management Area, ex *Tamias striatus*; *Tamiasciurus hudsonicus*;*Synaptomys cooperi*; *Microtus pennsylvanicus*Order **Acariformes**Suborder **Cryptostigmata** (= Oribatei)**Euphthiracaridae***Euphthiracarus* sp.Tobeatic Game Sanctuary, ex *Peromyscus leucopus*; *Clethrionomys gapperi**Rhysotritia* sp.Tobeatic Game Sanctuary, ex *Sorex palustris***Nothridae***Nothrus* sp.Tobeatic Game Sanctuary, ex *Peromyscus leucopus***Camisiidae***Platynothrus* sp.Tobeatic Game Sanctuary, ex *Blarina brevicauda*; *Peromyscus maniculatus*; *Zapus hudsonius*; *Ondatra zibethicus***Trhypochthoniidae***Trhypochthonius* sp.Tobeatic Game Sanctuary, ex *Microtus pennsylvanicus***Damaeidae***Epidamaeus* sp.Tobeatic Game Sanctuary, ex *Microtus pennsylvanicus***Ameronothridae***Hygroribates* sp.

Avonport Beach, Kings Co., on beach

Liacaridae*Adoristes* sp.Simpson Lake, Colchester Co., ex *Clethrionomys gapperi*

Metrioppiidae*Ceratoppia* sp.

Kearney Run, Halifax Co., on bark

Oribatulidae*Scheloribates* sp. (1)Tobeatic Game Sanctuary, ex *Microtus pennsylvanicus**Scheloribates* sp. (2)Sherbrooke, Guysborough Co., ex *Peromyscus maniculatus**Oribatula* sp.Tobeatic Game Sanctuary, ex *Peromyscus maniculatus*; *Peromyscus leucopus***Ceratozetidae***Fuscozetes* sp.Tobeatic Game Sanctuary, ex *Clethrionomys gapperi***Mycobatidae***Punctoribates* sp.Tobeatic Game Sanctuary, ex *Clethrionomys gapperi***Tegoribatidae***Lepidozetes* sp.Sherbrooke, Guysborough Co., ex *Peromyscus maniculatus***Order Acariformes**
Suborder Astigmata**Acaridae***Sancassania* (= *Caloglyphus*) sp.

Halifax, Halifax Co., in white-worm culture

Tyrophagus sp.

Truro, Colchester Co., in warehouse

Glycyhagidae*Glycyphagus* sp.

Truro, Colchester Co., in warehouse

Labidophoridae*Dermacarus hypudaei* (Koch)Rockingham, Halifax Co., ex *Napaeozapus insignis**Dermacarus ondatrae* R & WTobeatic Game Sanctuary, ex *Ondatra zibethicus***Order Acariformes**
Suborder Prostigmata**Myobiidae***Myobia* sp.Tobeatic Game Sanctuary, ex *Sorex cinereus*

Bdellidae*Cyta* sp.

Tobeatic Game Sanctuary, ex *Blarina brevicauda*
 Bridgewater, Lunenburg Co., in pitfall trap

Homocaligidae*Homocaligus* sp.

Tobeatic Game Sanctuary, ex *Clethrionomys gapperi*

Anystidae*Anystis* sp.

Tobeatic Game Sanctuary, ex *Lepus americanus*; *Peromyscus maniculatus*

Erythraeidae*Erythraeus* sp.

Bridgewater, Lunenburg Co., in pitfall trap
 Waverley, Halifax Co., in pitfall trap
 Sable Island, under washtub

Leptus sp.

Kearney Run, Halifax Co., on birch bark

Trombiculidae*Neotrombicula microti* sp. group

Tobeatic Game Sanctuary, ex *Tamiasciurus hudsonicus*; *Ondatra zibethicus*;
Microtus pennsylvanicus; *Clethrionomys gapperi*; *Peromyscus leucopus*
 Prospect, Halifax Co., ex *Zapus hudsonius*
 South Brookfield, Queens Co., ex *Blarina brevicauda*
 Sherbrooke, Guysborough Co., ex *Napaeozapus insignis*; *Clethrionomys gapperi*

Neotrombicula basignata sp. group

Tobeatic Game Sanctuary, ex *Microtus pennsylvanicus*; *Lepus americanus*

Trombicula sp.

Tobeatic Game Sanctuary, ex *Clethrionomys gapperi*; *Peromyscus leucopus*

Euschoengastia sp.

Tobeatic Game Sanctuary, ex *Clethrionomys gapperi*; *Microtus pennsylvanicus*
 South Brookfield, Queens Co., ex *Clethrionomys gapperi*
 Oxford, Cumberland Co., ex *Clethrionomys gapperi*

Trombidiidae*Allothrombium* sp.

Tobeatic Game Sanctuary, ex *Microtus pennsylvanicus*

Microtrombidium sp.

Farmington, Cumberland Co., in leaf litter

Rhinothrombium sp.

Bridgewater, Lunenburg Co., in pitfall trap

Eylaidae*Eylais* sp.

Tomahawk Lake, Halifax Co., in shallow water near shore

Hydrachnidae*Hydrachna* sp.Jollimore Pond, Halifax Co., ex water scorpion (*Ranatra* sp.)Class **Insecta**
Order **Siphonaptera****Pulicidae***Ctenocephalides felis* (Bouché) Cat FleaHalifax, Halifax Co., ex *Canis familiaris*; *Felis catus*; households; lawns*Pulex irritans* (Linnaeus) Human FleaCanso, Guysborough Co., ex *Homo sapiens***Hystrihopsyllidae***Stenoponia americana* (Baker)Simpson Lake, Colchester Co., ex *Napaeozapus insignis**Epitedia wenmanni* (Rothschild)Tobeatic Game Sanctuary, ex *Condylura cristata*Halifax, Halifax Co., ex *Peromyscus leucopus*Sherbrooke, Guysborough Co., ex *Microtus pennsylvanicus**Ctenophthalmus pseudagyrtus* BakerTobeatic Game Sanctuary, ex *Blarina brevicauda*; *Condylura cristata*;*Clethrionomys gapperi*; *Microtus pennsylvanicus*; *Peromyscus leucopus*Bridgewater, Lunenburg Co., ex *Blarina brevicauda*Lower Sackville, Halifax Co., ex *Peromyscus leucopus*Sherbrooke, Guysborough Co., ex *Tamias striatus*; *Microtus pennsylvanicus*Tomahawk Lake, Halifax Co., ex *Clethrionomys gapperi*; *Napaeozapus insignis*Simpson Lake, Colchester Co., ex *Clethrionomys gapperi*Whale Cove, Digby Co., ex *Blarina brevicauda*; *Clethrionomys gapperi**Doratopsylla blarinae* C. FoxWhale Cove, Digby Co., ex *Blarina brevicauda*South Brookfield, Queens Co., ex *Blarina brevicauda*Kelly's Mountain, near Englishtown, Victoria Co., ex *Blarina brevicauda**Corrodopsylla curvata curvata* (Rothschild)Tobeatic Game Sanctuary, ex *Sorex palustris*; *Sorex cinereus*; *Sorex fumeus*;
*Blarina brevicauda*Whale Cove, Digby Co., ex *Sorex cinereus*; *Blarina brevicauda*; *Zapus hudsonius*Tomahawk Lake, Halifax Co., ex *Sorex fumeus*Sherbrooke, Guysborough Co., ex *Sorex fumeus***Ceratophyllidae***Oropsylla arctomys* (Baker)Salt Springs, Pictou Co., ex *Marmota monax*Sherbrooke, Sherbrooke Co., Quebec, ex *Marmota monax**Opisodasys pseudarctomys* (Baker)Wolfville, Kings Co., ex *Glaucmys sabrinus**Orchopeas caedens durus* (Jordan)Tobeatic Game Sanctuary, ex *Tamiasciurus hudsonicus*; *Glaucmys sabrinus*;
*Peromyscus maniculatus*Stillwater, Guysborough Co., ex *Tamiasciurus hudsonicus*

Orchopeas leucopus (Baker)

Tobeatic Game Sanctuary, ex *Clethrionomys gapperi*; *Peromyscus leucopus*;
Peromyscus maniculatus

Lower Sackville, Halifax Co., ex *Peromyscus leucopus*

Simpson Lake, Colchester Co., ex *Clethrionomys gapperi*

Oxford, Cumberland Co., ex *Peromyscus maniculatus*

Baddeck, Victoria Co., ex *Peromyscus maniculatus*

Ceratophyllus diffinis Jordan

Sable Island, from nests of *Passerculus sandwichensis princeps*

Ceratophyllus gallinae (Schrank)

Sable Island, from swallow nest in collapsed building

Ceratophyllus styx riparius Jordan and Rothschild

Lower Wedgeport, Yarmouth Co., from swallow nesting box

Megabothris asio asio (Baker)

Tobeatic Game Sanctuary, ex *Condylura cristata*; *Zapus hudsonius*; *Microtus pennsylvanicus*; *Synaptomys cooperi*

Bridgewater, Lunenburg Co., ex *Blarina brevicauda*; *Microtus pennsylvanicus*

Tomahawk Lake, Halifax Co., ex *Microtus pennsylvanicus*

Kelly's Mountain, near Englishtown, Victoria Co., ex *Napaeozapus insignis*

Baddeck Bridge, Victoria Co., ex *Microtus pennsylvanicus*

Ceratophyllidae*Megabothris quirini* (Rothschild)

Tobeatic Game Sanctuary, ex *Blarina brevicauda*; *Clethrionomys gapperi*;
Microtus pennsylvanicus; *Peromyscus maniculatus*; *Peromyscus leucopus*

Whale Cove, Digby Co., ex *Clethrionomys gapperi*; *Peromyscus leucopus*; *Zapus hudsonius*

Bridgewater, Lunenburg Co., ex *Clethrionomys gapperi*

Lower Sackville, Halifax Co., ex *Zapus hudsonius*

Tomahawk Lake, Halifax Co., ex *Clethrionomys gapperi*; *Napaeozapus insignis*

Oxford, Cumberland Co., ex *Zapus hudsonius*

Simpson Lake, Colchester Co., ex *Clethrionomys gapperi*; *Napaeozapus insignis*

Sherbrooke, Guysborough Co., ex *Clethrionomys gapperi*; *Napaeozapus insignis*

Monopsyllus vison (Baker)

Tobeatic Game Sanctuary, ex *Tamiasciurus hudsonicus*; *Peromyscus maniculatus*;
Peromyscus leucopus; *Clethrionomys gapperi*; *Procyon lotor*

Nosopsyllus fasciatus (Bosc)

Halifax, Halifax Co., ex *Rattus norvegicus*

Leptopsyllidae*Peromyscopsylla catatina* (Jordan)

Tobeatic Game Sanctuary, ex *Clethrionomys gapperi*

Whale Cove, Digby Co., ex *Clethrionomys gapperi*

Simpson Lake, Colchester Co., ex *Clethrionomys gapperi*

Sherbrooke, Guysborough Co., ex *Clethrionomys gapperi*

Leptopsyllidae*Peromyscopsylla hesperomys hesperomys* (Baker)

Tobeatic Game Sanctuary, ex *Peromyscus maniculatus*; *Peromyscus leucopus*

Whale Cove, Digby Co., ex *Peromyscus leucopus*

Ischnopsyllidae

- Myodopsylla insignis* (Rothschild)
Tobeatic Game Sanctuary, ex *Myotis* sp.

Order Mallophaga**Philopteridae**

- Saemundssonina lari* (Fabricius)
Sable Island, ex *Larus argentatus*
- Halipeurus* sp.
Sable Island, ex *Puffinus gravis*
- Trabeculus hexakon* (Waterston)
Sable Island, ex *Puffinus gravis*
- Quadriceps* sp. prob. *klatti* Timmermann
Bedford, Halifax Co., ex *Plautus alle*
Sable Island, ex *Larus argentatus*

Menoponidae

- Procellariphaga paulula* (Kellogg & Chapman)
Sable Island, ex *Puffinus gravis*

Trichodectidae

- Eutrichophilus setosus* (Giebel)
Timberlea, Halifax Co., ex *Erethizon dorsatum*

Order Anoplura**Hoplopleuridae**

- Hoplopleura hesperomydis* (Osborn)
Kelly's Mountain, near Englishtown, Victoria Co., ex *Peromyscus maniculatus*

Pediculidae

- Pthirus pubis* (Linnaeus)
Spryfield, Halifax Co., ex *Homo sapiens*
Lunenburg, Lunenburg Co., ex *Homo sapiens*

Haematopinidae

- Haematopinus suis* (Linnaeus)
MacDonald College, Ste Anne de Belleveau, Quebec, ex *Sus scrofa*

Appendix

Number of species recorded on each host

Host	Mites	Ticks	Fleas	Lice
MAMMALS				
<i>Sorex cinereus</i>	6	1	1	
<i>Sorex fumeus</i>		1	1	
<i>Sorex palustris</i>	5		1	
<i>Blarina brevicauda</i>	15	1	6	
<i>Condylura cristata</i>	3		3	
<i>Myotis</i> sp.	2		1	
<i>Lepus americanus</i>	2	2		
<i>Tamiasciurus hudsonicus</i>	1	3	2	
<i>Marmota monax</i>	1		1	
<i>Tamias striatus</i>		1	1	
<i>Glaucomys sabrinus</i>	1	1	2	
<i>Peromyscus maniculatus</i>	10	1	5	1
<i>Peromyscus leucopus</i>	20	2	7	
<i>Synaptomys cooperi</i>	2	2	1	
<i>Clethrionomys gapperi</i>	26	2	6	
<i>Microtus pennsylvanicus</i>	24	4	5	
<i>Ondatra zibethicus</i>	4	1		
<i>Rattus norvegicus</i>			1	
<i>Zapus hudsonius</i>	9	2	3	
<i>Napaeozapus insignis</i>	5	3	4	
<i>Erethizon dorsatum</i>		2		1
<i>Canis familiaris</i>		1	1	
<i>Ursus americanus</i>		1		
<i>Procyon lotor</i>	1	2	1	
<i>Mustela erminea</i>		1		
<i>Felis catus</i>			1	
<i>Sus scrofa</i>				1
<i>Odocoileus virginianus</i>		1		
<i>Alces alces</i>		1		
<i>Homo sapiens</i>		1	1	1
BIRDS				
<i>Puffinus gravis</i>				3
<i>Canachites canadensis</i>		1		
<i>Bonasa umbellus</i>		1		
<i>Larus argentatus</i>				2
<i>Plautus alle</i>				1
<i>Hirundinidae</i>	1		2	
<i>Turdus migratorius</i>		1		
<i>Hylocichla ustulata</i>		1		
<i>Icteria virens</i>	1			
<i>Passerculus sandwichensis princeps</i>	1		1	
<i>Junco hyemalis</i>		1		

ADDITIONS TO THE MACROLEPIDOPTERA OF NOVA SCOTIA

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A list is presented of 23 species of Macrolepidoptera collected since the publication of "The Lepidoptera of Nova Scotia: Part 1 (Macrolepidoptera)" by Ferguson (1955). Localities, dates of capture, collectors, sexes, locations of specimens, and other relevant data are given.

Introduction

Since the publication of "The Lepidoptera of Nova Scotia" (Ferguson 1955), extensive field work by collectors in the province has added considerable information to our knowledge of these forms. As a result, new provincial records have been obtained, expanding the known distribution of many species occurring in northeastern North America.

Collecting in the past 20 years has been conducted throughout the province, especially in those areas which have not received sufficient entomological attention in the past. These areas have included Digby and Yarmouth Counties, the northeastern portion of Halifax County, and the central area of Cape Breton Island. As a result, the total number of Macrolepidoptera species listed for the province is now 859, an increase of 23 species over the 836 listed by Ferguson (1955).

The species are arranged here according to McDunnough (1938), using the taxonomy proposed by Forbes (1954) and various other authors. Localities, dates of collection, collectors, sexes of the specimens, and any other relevant information are given. Specimens are located in the Nova Scotia Museum (NSM), Canadian National Collection (CNC), United States National Museum (USNM), American Museum of Natural History (AMNH), James Edsall Collection (JEC), and the Kenneth Neil Collection (KNC).

I thank Barry Wright of the Nova Scotia Museum, Halifax, who supplied data and specimens and who reviewed the final manuscript; James Edsall of Halifax, who supplied data and specimens from his personal collection; and Drs. E.G. Munroe and W.C. McGuffin of the Biosystematics Research Institute, Ottawa, who supplied data and specimens from the Canadian National Collection.

Nymphalidae

Nymphalis urticae (L.)

Halifax, Halifax Co., 7 November 1970, F. Scott. (NSM). 1 male. Collected after the specimen had flown from a crate shipped from Oxford, England, on 23 August 1970 (Scott & Wright 1972).

Lycaenidae

Callophyrs (Incisalia) lanoraieensis Sheppard

Gold River, Lunenburg Co., 27 April 1969, P. Ward. (NSM). 1 female.

Bridgewater, Lunenburg Co., 11 May 1969, B. Wright. (NSM). 1 female.

Gold River, Lunenburg Co., 9 June 1969, J. Edsall. (JEC). 1 male and 1 female.

An additional record is cited by the Forest Insect Survey (McGugan 1958) as having been taken in Lunenburg Co., but the exact locality and date of capture are not given.

Hesperidae

Thymelicus lineola (Ochs.)

First collected in 1966 along a railway siding in the west end of Halifax. This species has since become abundant throughout the entire Halifax area. Also seen in the Annapolis Valley and in Sydney Mines (Eberlie 1978). Flight dates from 27 June to 10 August.

Sphingidae

Sphinx canadensis Bvd.

Armdale, Halifax Co., 7 July 1976, K. Neil. (KNC). 1 male.

Darapsa myron (Cram.)

Greenwood, Kings Co., B. Wright. The specimen was determined by B. Wright shortly after which it was deposited in the USNM. Date of capture and sex of the specimen not known. It is believed that this specimen came from Winnipeg by military aircraft.

Noctuidae

Agrotis sp.

Sable Island. Flight dates from 14 June to 25 July. Specimens from Sable Island resemble *A. stigmosa* Morr. but appears to be a distinct species.

Noctua speciosa mixta (Wlk.)

Bog near Baddeck, Victoria Co., 30 July 1970, D.C. Ferguson and B. Wright. (NSM). 7 females.

Near Baddeck Bridge, Baddeck River, Victoria Co., 7 August 1970, D.C. Ferguson and B. Wright. (NSM). 1 female.

Lithophane innominata (Smith), normal form.

Armdale, Halifax Co., 30 April 1971, J. Edsall. (JEC). 1 male.

Armdale, Halifax Co., 27 October 1971, J. Edsall. (JEC). 1 male.

Armdale, Halifax Co., 10 May 1974, K. Neil. (KNC). 1 male.

Armdale, Halifax Co., 19 May 1974, K. Neil. (KNC). 1 male.

Oligia sp.

Coldbrook, Kings Co., 21 July 1971, K. Neil. (KNC). 1 male.

Killag Road, Halifax Co., 27 July 1972, J. Edsall. (JEC). 2 males.

Armdale, Halifax Co., 27 July 1972, K. Neil. (KNC). 1 female.

This species, previously determined as *O. tonsa* Grote is currently being described as a new species by J.G. Franclemont of Cornell University.

Papaipema sp.

Sable Island, 10 September 1977, B. Wright. (AMNH). 1 male.

Currently being described by F. Quinter for a future volume of *The Moths of America North of Mexico*.

Hypocoena rufostrigata Pack.

Belliveau Cove, Digby Co., 3 August 1974, K. Neil. (KNC). 1 male.

Condica cupentia (Cram.)

Point Pleasant Park, Halifax, Halifax Co., 13 October 1954, D.C. Ferguson. (NSM). 2 males.

A southern species sometimes straying north in autumn. Determinations made by D.C. Ferguson.

Platysenta sutor (Gn.)

Lake Kejimikujik, Queens Co., 17 September 1957, D.C. Ferguson. (NSM). 2 males.

Armdale, Halifax Co., 26 September 1975, K. Neil. (KNC). 1 male.

Spodoptera exigua (Hbn.)

Armdale, Halifax Co., 4 October 1971, K. Neil. (KNC). 2 males.

Magusa orbifera (Wlk.)

Debert, Colchester Co., 4 September 1957, W. Harrington. (NSM). 1 male.

Bellura diffusa (Grt.)

Truro, Colchester Co., 14 July 1969, K. Neil. (NSM). 1 male.

Halfway Brook, 3 mi. N. of Sheet Harbour, Halifax Co., 7 July 1972, J. Edsall. (JEC). 1 male.

Halfway Brook, 3 mi. N. of Sheet Harbour, Halifax Co., 23 July 1972, J. Edsall. (JEC). 2 males, 1 female.

Trichoplusia oxygramma (Hbn.)

Halfway Brook, 3 mi. N. of Sheet Harbour, Halifax Co., 11 August 1973, K. Neil. (KNC). 1 male.

Thysania zenobia (Cram.)

Dartmouth, Halifax Co., late summer or early autumn of 1944, C. Eisner. (NSM). 1 male.

Hypocala andremona (Cram.)

Debert, Colchester Co., 18 September 1957, W. Harrington. (CNC). Sex of specimen unknown.

Dyspyralis nigellus Stkr.

Lake Kejimikujik, Queens Co., 20 July 1957, D.C. Ferguson. (NSM). 2 males.

Lake Kejimikujik, Queens Co., 22 July 1957, D.C. Ferguson. (NSM). 1 male.

Lake Kejimikujik, Queens Co., 14 July 1961, D.C. Ferguson. (NSM). 1 male.

Lake Kejimikujik, Queens Co., 15 July 1961, D.C. Ferguson. (NSM). 1 male.

Pleasant River, Queens Co., 3 August 1968, B. Wright. (NSM). 1 male.

Liparidae

Orgyia leucostigma ssp.

Sable Island. Flight dates from 3 August to 11 September.

This recently discovered subspecies is quite different from the mainland *O. leucostigma plagiata* (Wlk.) and is being described by K. Neil.

Geometridae

Chlorchlystis rectangulata (L.)

Smiley's Brook Provincial Park, near Brooklyn, Hants Co., 20 July 1970, D.C. Ferguson and B. Wright. (USNM). 1 specimen, sex unknown. (Ferguson 1972).

Middle River, Victoria Co., 27 July 1970, D.C. Ferguson and B. Wright. 2 males, 1 female in NSM. 3 remaining specimens in USNM; sex unknown. (Ferguson 1972).

Baddeck River, near Baddeck Bridge, Victoria Co., 29 July 1970, D.C. Ferguson and B. Wright. 1 male in NSM, 1 specimen in USNM; sex unknown. (Ferguson 1972).

Smiley's Brook Provincial Park, near Brooklyn, Hants Co., 23 July 1972, D.C. Ferguson. (USNM). 1 female.

Sheet Harbour, Halifax Co., 16 July 1973, J. Edsall. (KNC). 1 male.

Armdale, Halifax Co., 23 July 1974, K. Neil. (KNC). 1 female.

Armdale, Halifax Co., 13 July 1975, K. Neil. (KNC). 1 male.

Eulythis mellinata (F.)

Armdale, Halifax Co., 31 July 1972, J. Edsall. (NSM). 1 female.

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NOTES ON THE ECOLOGY AND GROWTH OF *IDOTEA PHOSPHOREA* HARGER (CRUSTACEA: ISOPODA)

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A small population of *Idotea phosphorea* Harger was monitored at irregular intervals from 1976 to 1978. The general biology was similar to other idoteids investigated, and measurements of head width, body length, and wet and dry weight allow the conversion into energy equivalents of remains found in gut analyses.

Introduction

In recent years there has been a great deal of research on the flora and fauna of the Bay of Fundy and its estuaries. Particular attention has been given (Strong 1978; 1979) to the life cycle and energy relations of *Idotea baltica* (Pallas), an inhabitant of intertidal *Ascophyllum nodosum* (L.) LeJolis. Several other isopod species occur in lesser numbers within these seaweed mats, among them a poorly described congener. This isopod, *Idotea phosphorea* Harger, has apparently hitherto never been examined in sufficient detail to warrant a published description of its ecology, although it has been listed in faunal studies (Richardson 1901; 1905; Bousfield & Leim 1959; Gosner 1971). It is eaten by black ducks (*Anas rubripes* Brewster), several species of groundfish including *Cottunculus thompsoni* (Günther), *Anguilla rostrata* (LeSueur), *Urophycis tenuis* (Mitchell), and *Raja erinacea* (Mitchell) and probably other vertebrates. This report provides some preliminary biological observations, together with selected measurements that allow easy conversion to energy units (calories).

Materials and Methods

In total 330 *Idotea phosphorea* were collected on 12 occasions between May 1976 and June 1978 at Cape Blomidon, N.S. (45°12'N, 64°20'W). All were returned alive to the laboratory and were killed by freezing at -15°C.

Isopods were subsequently thawed and the length from cephalon to telson measured to the nearest 0.1 mm with handheld calipers. Width of the cephalon was also determined to the nearest 0.05 mm by a stage micrometer fitted to a compound microscope. Each isopod was sexed, any embryos in the female brood pouches were counted and removed, and the fresh weight was determined to the nearest mg after blotting on paper towel for 1 minute. Finally, the dry weight was determined to the nearest 0.01 mg on an electrobalance after drying for 24 hours at 70°C in a vacuum oven.

Calorific equivalents were obtained with a microbomb calorimeter following techniques outlined elsewhere for *Idotea baltica* (Strong & Daborn 1978). Ash contents were determined on separate pellets according to Reiners and Reiners (1972).

Each animal collected in 1976 (total = 93) was assigned a color score of 1 to 4 where 1 represented totally light (white) individuals, 4 included isopods that were completely dark (absence of any white), and 2 and 3 indicated intermediate conditions. The distribution of these scores within the population was then compared to the microhabitat from which the isopods were collected.

Results and Discussion

Life Cycle

As with other species of *Idotea*, the developing embryos pass through 4 embryonic stages after extrusion into the brood pouch, the fourth of which corresponds to the first free living instar. These stages are similar to those described for *Idotea baltica* (Strong 1978). All embryos in a single brood were at the same stage of development and were of a similar size.

Fecundity of crustaceans has been described by a variety of equations, including linear (Jones & Naylor 1971), semi-logarithmic (Daborn 1977), and logarithmic (Shedder 1977) formulae. The linear relationship, which had the greatest coefficient of correlation ($r=0.685$), was accordingly chosen, although it accounts for only 46.9% of the variation (Fig 1). The smallest length of any female with a brood collected in the field was 10 mm.

Although collections of *I. phosphorea* were obtained at somewhat irregular intervals, sufficient data were available to identify the major period of breeding activity (Fig 2). In 1977, deposition of ova into the brood pouches presumably occurred before April, and by June all females carried broods. Release of juveniles was maximal in July and August, and in September no females carried young. In 1978, however, reproduction presumably occurred somewhat earlier. The duration of embryonic development is probably within the range of 1 to 2 months reported for other members of the genus (Kjennerud 1950; Naylor 1955; Shedder 1977; Strong 1978).

Both the mean length of each sex (Fig 3) and the sex ratio (Fig 4) on each collecting date of 1977 indicate that males have a shorter life span than females. Both sexes die after reproducing. Males apparently return to the intertidal zone earlier in the

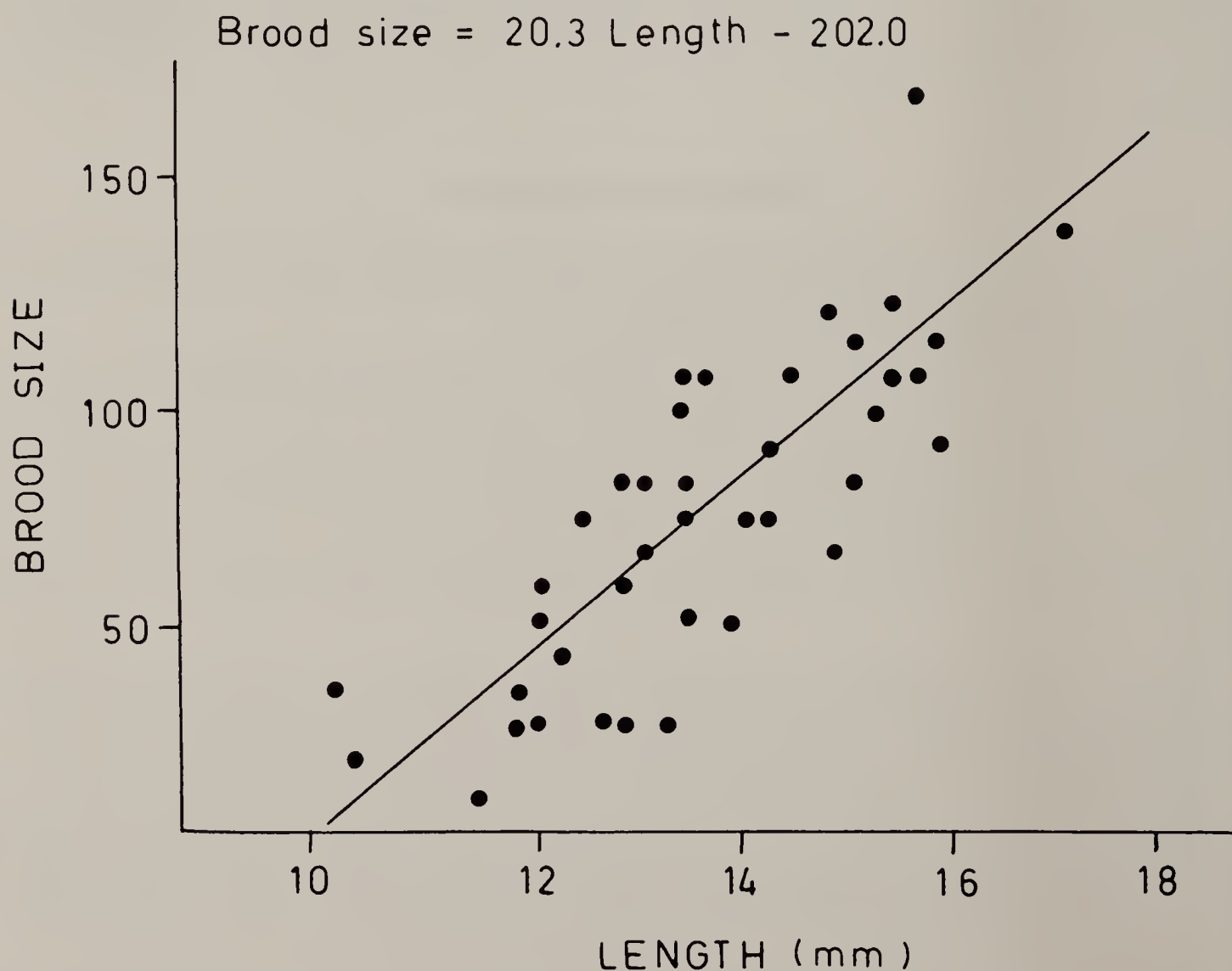


Fig 1. Relationship between length of female *I. phosphorea* and number of embryos in brood pouch (stages I-III).

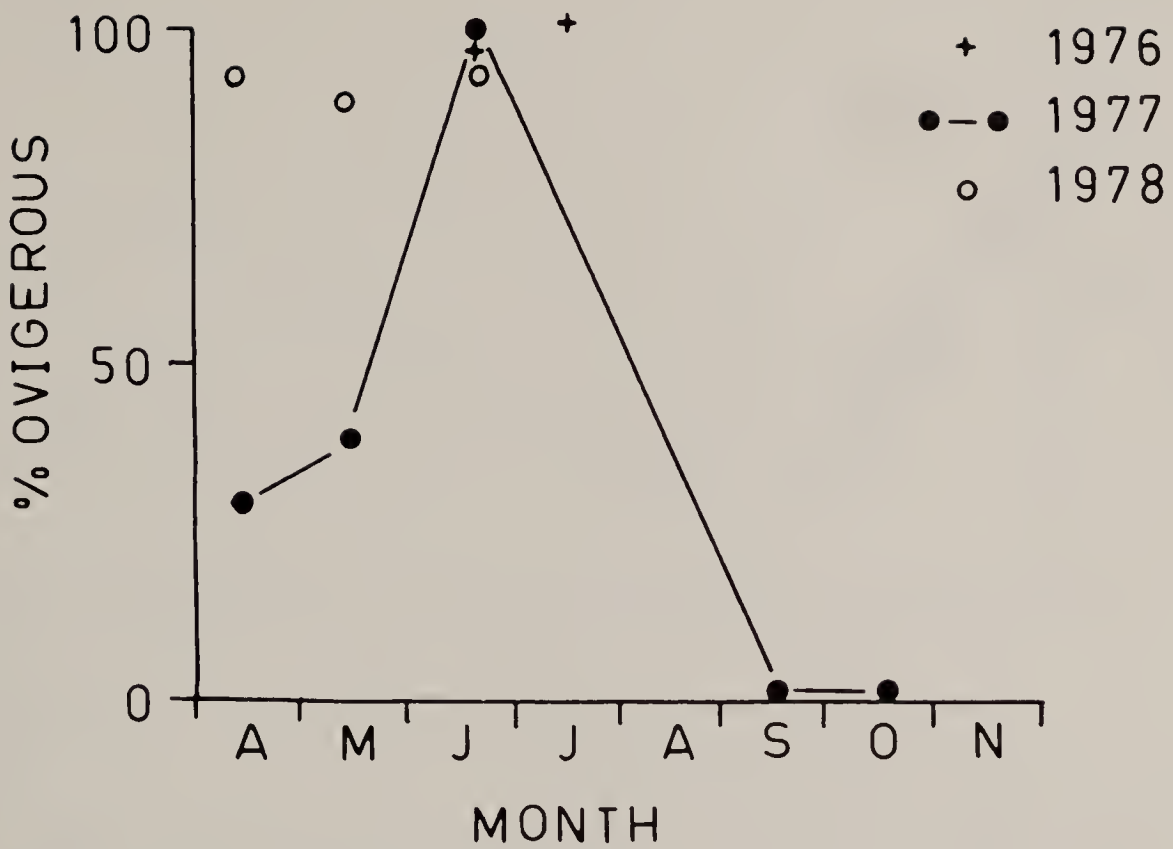


Fig 2. Percent of females ovigerous (embryos in brood pouches) on each collecting date.

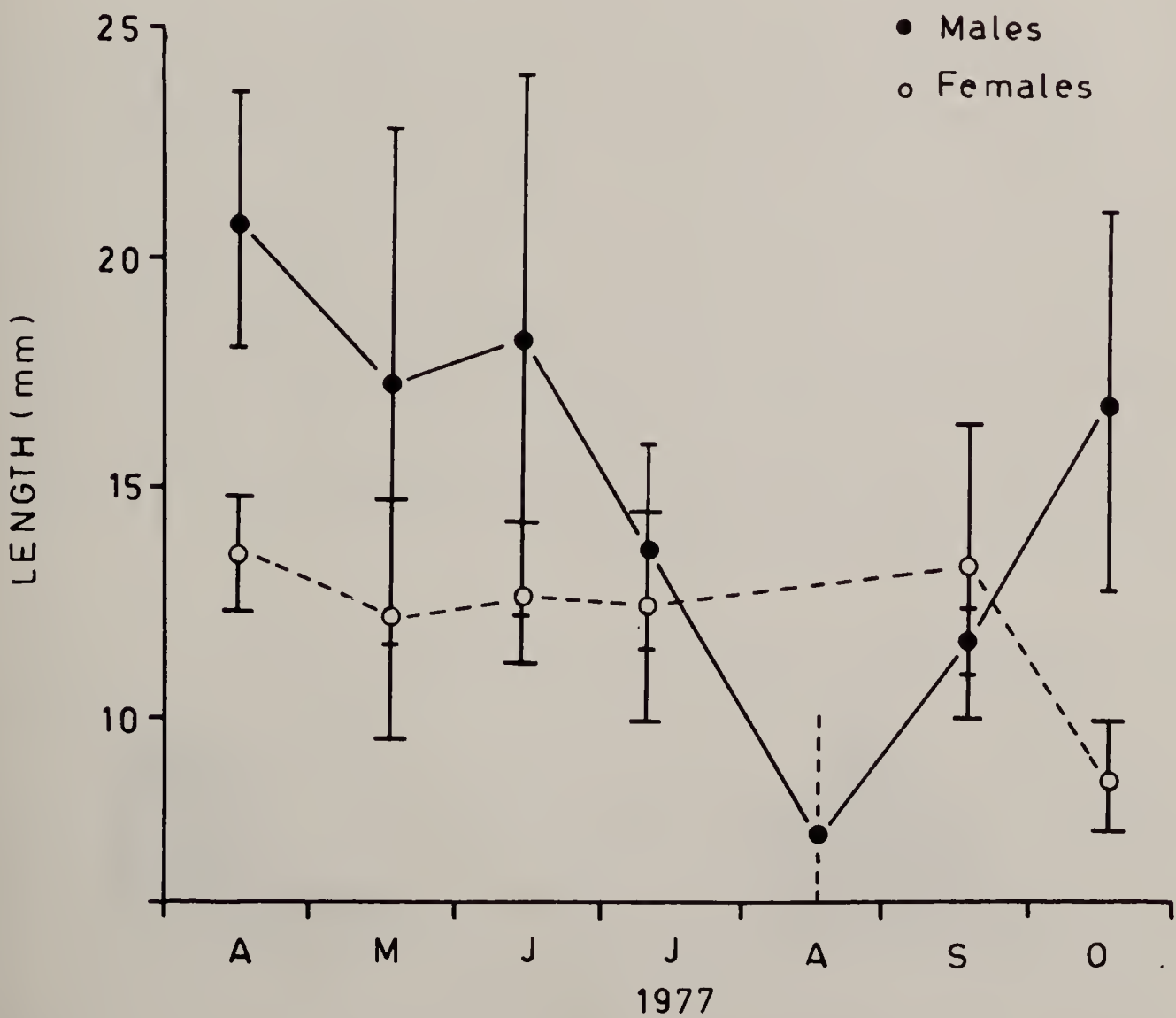


Fig 3. Mean lengths of males and females on each collecting date of 1977. Only 2 males and no females were collected in August. Vertical lines represent $\pm$ s.d.

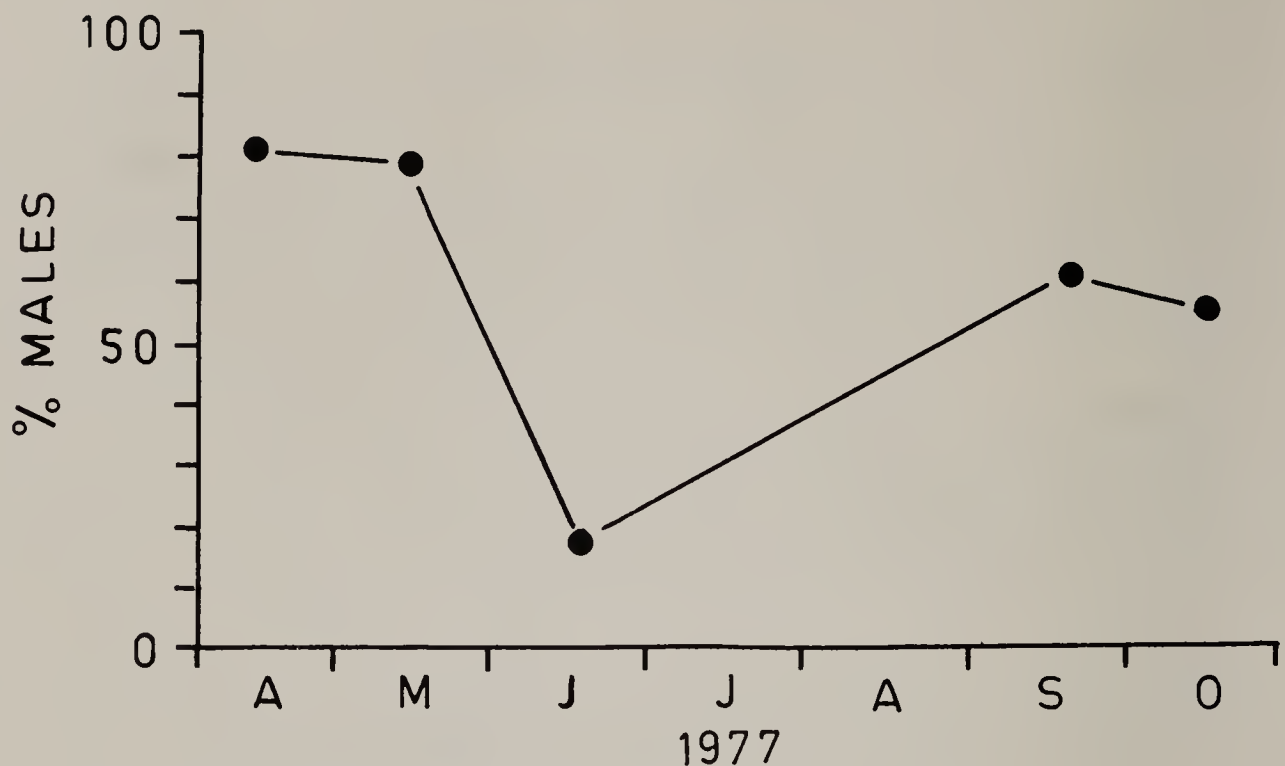


Fig 4. Percent males on each collecting date.

spring than do females, which is also true for *I. baltica* (Strong 1978). Once the broods are deposited into the brood pouches, the largest males die, and the sex ratio declines sharply in favor of females. Following release of the young, the large females also die, and the sex ratio again approaches unity.

Microhabitat

I. phosphorea were collected from two different areas of the same beach in each of the 3 summers it was visited. In addition to those isopods collected from *A. nodosum* mats, many were found clinging either to the red alga *Gigartina stellata* (Stakh. in With.) Batt. or to the undersides of larger stones in the area. A distinct color polymorphism was evident between the two microhabitats (Fig 5). Considering that these microhabitats are not separated by either a physical barrier or excessive distance, movement of isopods between the 2 areas is likely. Although complete color change is probably not possible, lightening or darkening of the existing color patterns can be achieved by chromatophore activity. Presumably chromatophore expansion and contraction occurs in response to background color. In this way, isopods moving from one area to the other can rapidly match whatever substrate they contact. Similar color and pattern polymorphism has been reported elsewhere for *I. baltica* (Matzdorff 1883; Pieron 1913; 1914; Peabody 1959; Suneson 1947; Strong 1977) and *I. neglecta* (Kjennerud 1950).

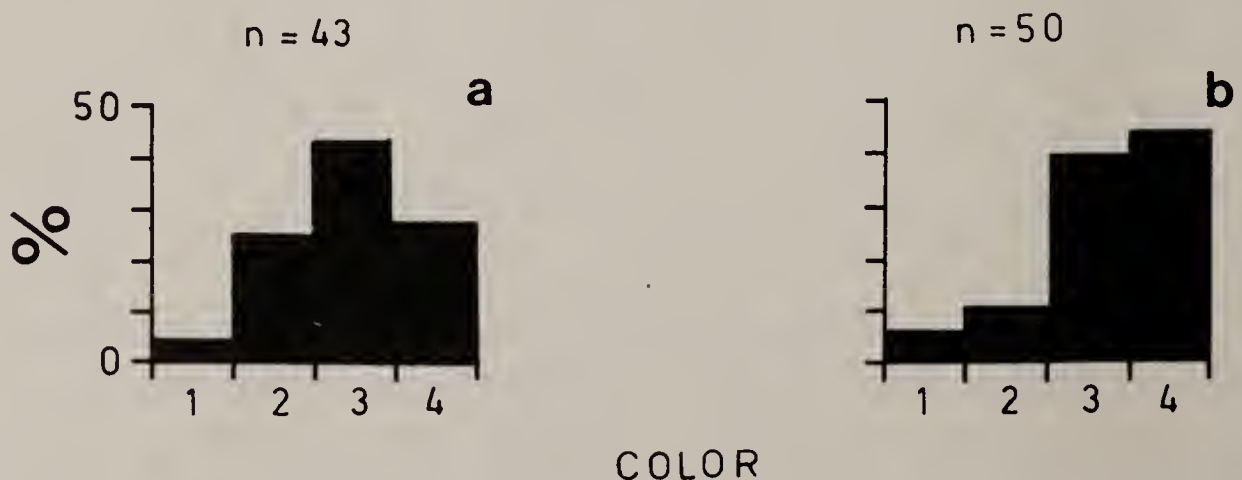


Fig 5. Percent of total *I. phosphorea* collected from each microhabitat in 1976 as a function of body color. 1 - white, 2 - mostly white, 3 - mostly dark, 4 - dark. a - amongst *A. nodosum*, b - under stones or amongst *G. stellata*.

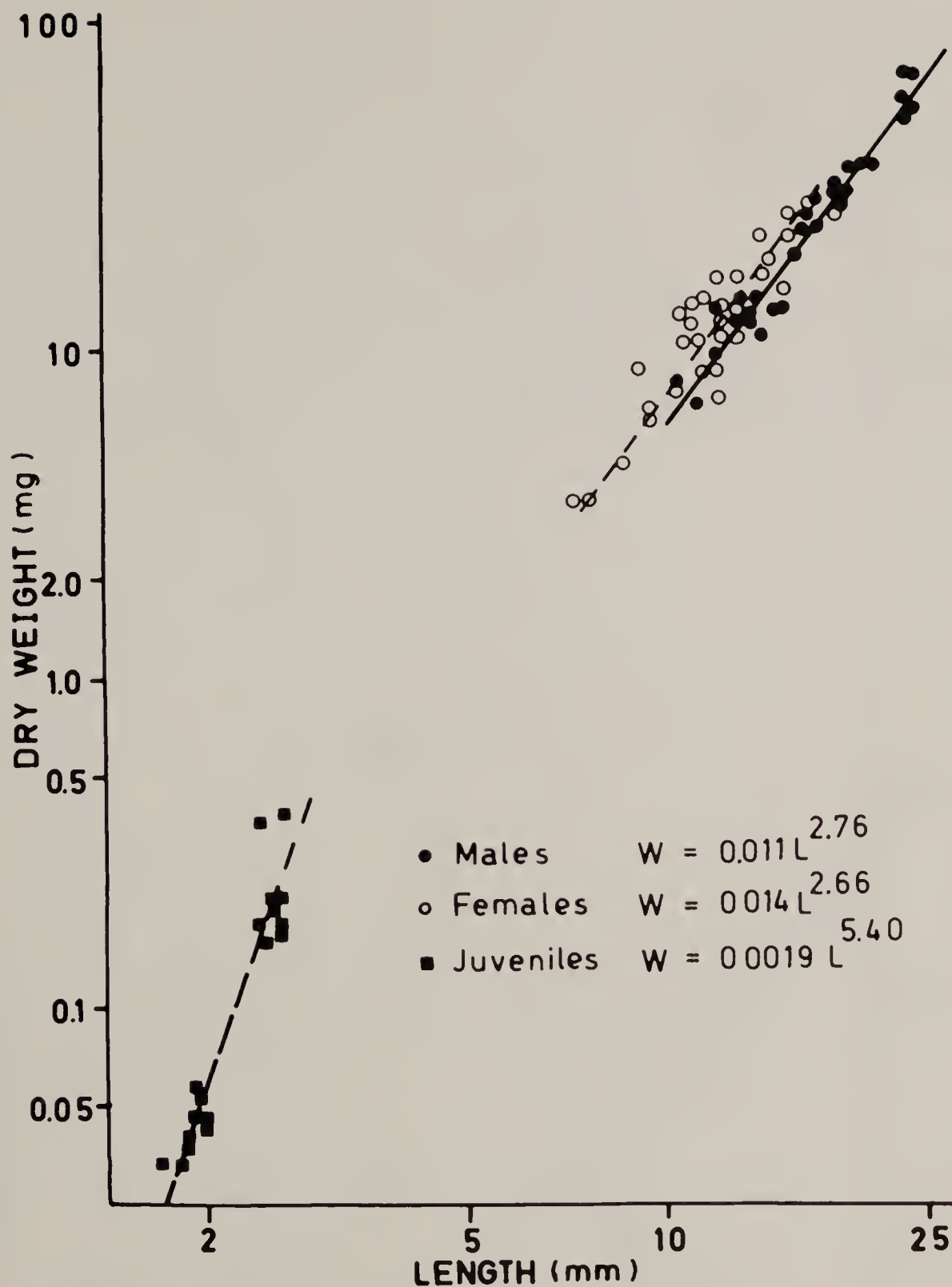


Fig 6. Relationships between length and dry weight of *I. phosphorea*.

Energy Content

Although the length of an animal is convenient for measurement, weight is biologically more meaningful. Accordingly, length-weight relationships were derived for *I. phosphorea* (Fig 6).

The regression coefficients for males and females are within the range of values reported for other *Idotea* (Howes 1939; Khmeleva 1971; Romanova 1974; Strel'nikova 1970), but the value for juveniles is most certainly not. In fact, an exponent greater than 3 is rather surprising, considering that the addition of length at such a small size (ca. 2.0 mm when released from the brood pouch) would seem more advantageous than the accumulation of biomass. Extensive morphological differentiation does not occur within this length range, and because only a few measurements were available, the reason for such a high exponent is unknown.

In addition, the relationship between fresh weight and dry weight was determined for both sexes together (Fig 7). Individual relationships for each sex did not seem justified because of the errors involved in measurement of fresh weight.

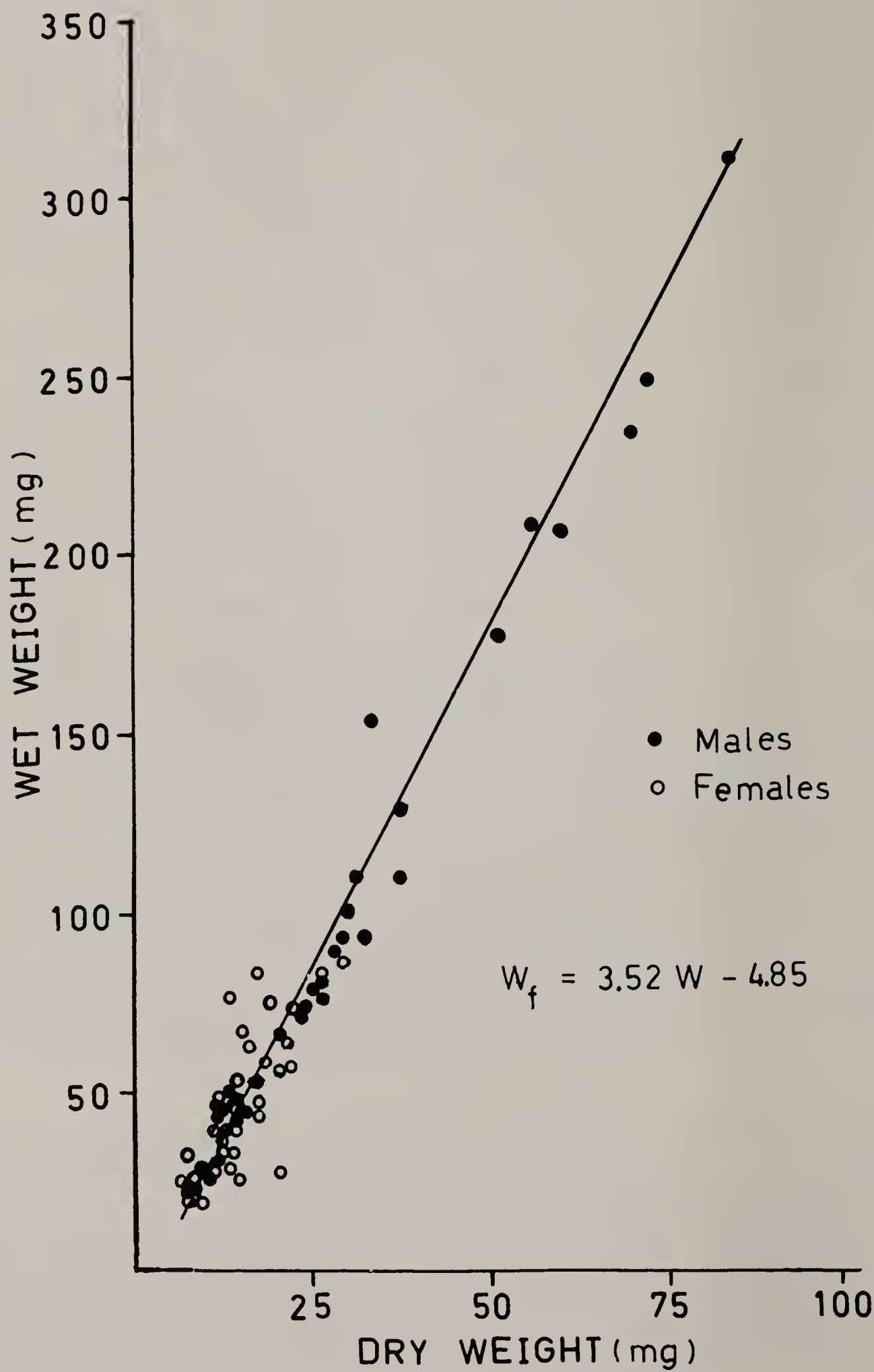


Fig 7. Relationship between wet and dry weight of *I. phosphorea*.

Examination of gut contents of benthic carnivores frequently reveals many fragments of crustacean integument that are difficult to identify. The cephalon, however, is relatively easy to identify in *I. phosphorea*. Therefore, the relationship between its width and the length of the animal was derived to permit conversion of head fragments in gut analyses into units of length. Since sex cannot be determined from the cephalon only, males and females were combined.

Using equations of Figures 7 and 8, it is possible to convert either measurements of length into fresh or dry weight, whichever is required.

In terms of energy to be gained by a predator, the energy content of the prey is of greater importance than weight (Table 1). Ovigerous females (those with ova in the brood pouches) contain 36% more energy per unit weight than those with no embryos. On the whole, values in Table 1 are similar to those reported for *I. baltica* (Shapunov 1969; Strong & Daborn 1978).

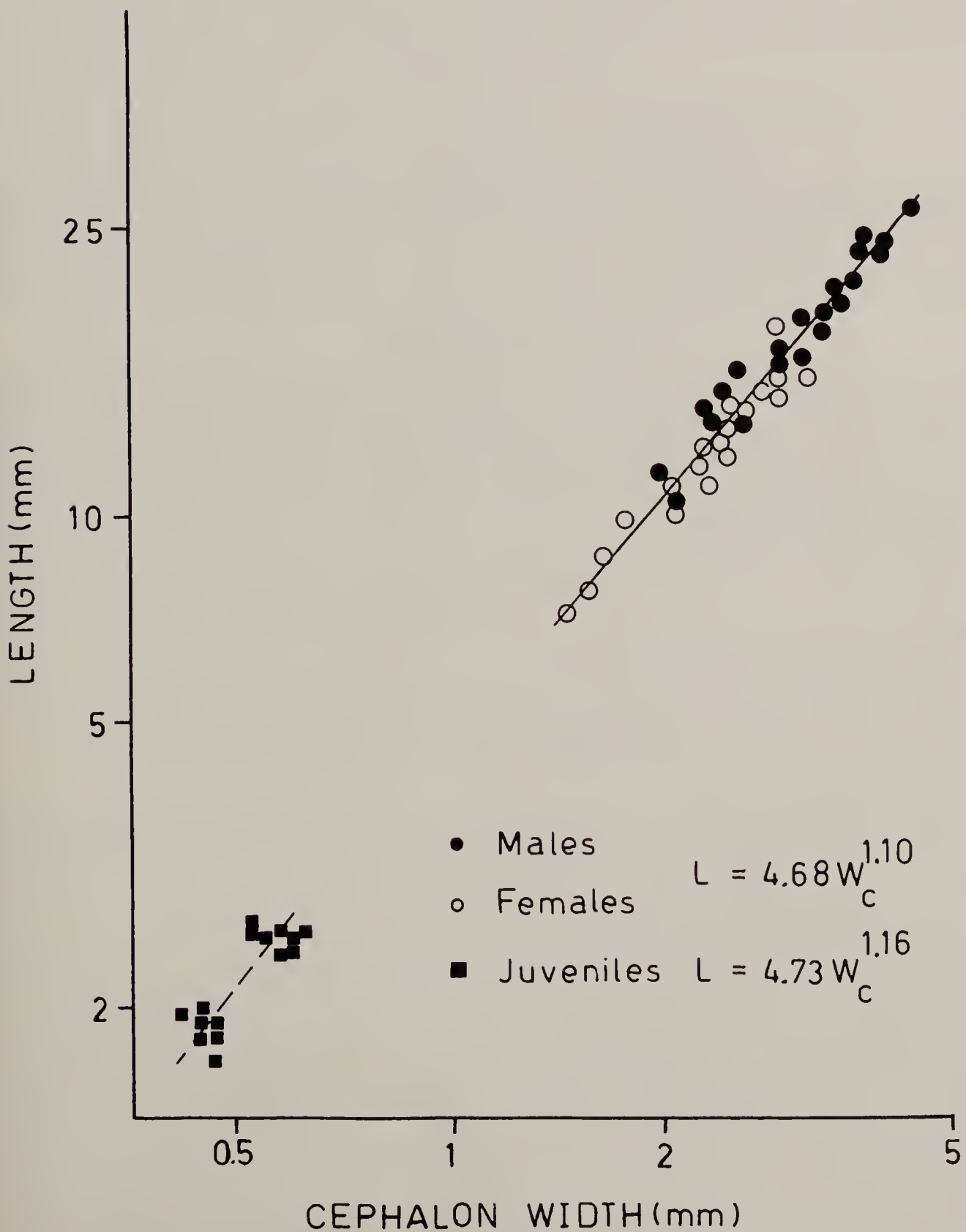


Fig 8. Relationships between cephalon width and body length of *I. phosphorea*.

Table 1. Ash and calorific contents of *Idotea phosphorea*.

Class	Cal/mg dry weight (± 1 s.d.)		% ash (± 1 s.d.)	
Juveniles	2.33	(1)**	n/a*	
Males	2.57 $\pm$ 0.12	(12)	40.08 $\pm$ 2.48	(9)
Females (ovigerous)	2.92 $\pm$ 0.16	(6)	36.27 $\pm$ 4.02	(4)
Females (post-ovigerous)	2.14 $\pm$ 0.05	(4)	40.10 $\pm$ 0.86	(2)
Adult mean	2.59 $\pm$ 0.29	(22)	39.07 $\pm$ 3.32	(15)

*not available

**number of determinations

It must be re-emphasized that our knowledge of this species is still fragmentary. The collection of data in this report is admittedly incomplete, but it is useful in that one can convert measurements of cephalon width, which might be available from gut analyses, into units of length, weight, or energy, whichever is most appropriate.

Acknowledgments

We are grateful to Sherman Boates and Diana Imrie for providing unpublished observations on bird and fish gut contents, and to Terry Quinney and an anonymous referee for evaluating the manuscript. This research was supported by a NRC operating grant (No. A9697) to one of us (GRD) and an Acadia University graduate fellowship to the other (KWS).

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THE PERSISTENCE OF FENITROTHION INSECTICIDE IN BALSAM FIR *ABIES BALSAMEA* (L.) MILL. DEER BROWSE

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From 30 September 1976 to 30 September 1977, 2 vegetation plots were monitored bi-monthly to establish fenitrothion concentrations on balsam fir browse. The data obtained indicate persistence of fenitrothion on the sprayed and control plots. The sprayed quadrant had an average concentration of 0.31 ppm over the 12 month period whereas the control plot, which was not sprayed in 1976 or 1977, had an average concentration of 0.05 ppm. The control plot was sprayed during the 1975 spray program. Fenitroxon was detected in 2 of the samples taken from the sprayed plot. None was detected within the control plot. In reviewing the literature, there is no evidence that a fenitrothion concentration of the magnitude detected would have obvious effects on deer populations.

Introduction

Fenitrothion, O, O-dimethyl O-(4 nitro-m-tolyl) phosphorothioate, has been used since 1969 to control spruce budworm *Choristoneura fumiferama* (Clemens) in the forest of the Canan Game Reserve, New Brunswick. Various workers (Shishido 1972; Miyamoto 1969; Nigam 1971) have previously shown the short persistence and fate of fenitrothion in a natural environment. Furthermore Yule and Duffy (1972) and Sundaram (1974) demonstrated that fenitrothion can persist in a coniferous forest in concentrations ranging from 0.80 to 0.14 ppm over a 5 year period.

This project evaluated residual concentrations of fenitrothion and its oxygen analogue in balsam fir *Abies balsamea* (L.) Mill. Previous studies by Crête (1976) and unpublished data obtained from the monitoring of deer yards in southeastern New Brunswick indicate that balsam fir plays an important role in the diet of the White-tail deer *Odocoileus virginianus* (Zimmermann) during late spring yarding. It was anticipated that a high concentration of fenitrothion might have a negative effect on the intestinal rumen flora.

Study Area and Methods

The field experiment was located in the Canaan Game Reserve area 21 miles northwest of Moncton within longitude 65° 30' and latitude 46°20'. The experimental spray plot T-1 was 20 ft from Alward Brook inside spray block 279 of the 1977 spray program. The control plot C-1 was along the south side of Canaan River about 11 miles from the sprayed plot. The control plot was not sprayed during the 1976 and 1977 programs.

The sampling plots were forested areas dominated by red spruce *Picea rubens* Moench and black spruce *Picea mariana* (L.) Mill. Logging of these species occurred 10 years ago in the areas where the experimental plots were established. A young growth of balsam fir varying from 4 to 7 ft in height formed the major, lower vegetation canopy within the plots. The upper canopy was composed of red maple (*Acer rubrum* K. Koch), grey birch (*Betula populifolia* Marsl.), and aspen (*Populus tremuloides* Michx.). Both habitats selected were identical in vegetation composition, and these plots were located in areas where deer browsing had been observed during the winter of 1977. The sprayed plot was sprayed with 2 applications of 3 oz AI/acre of fenitrothion in an oil emulsion between 26 May and 3 June 1977.

The sampling plots measured 10 m². Samples were collected on the 30th and 15th

day of each month from 30 September 1976 to 30 September 1977; a total of 38 samples was collected and processed.

The browse samples were clipped with pole and hand pruners. About 10 cm were cut at random from terminal twigs ensuring a representative sampling of the entire tree. Twenty to 30 g were cut into small pieces and placed in 110 ml glass bottles. While in the field, the bottles were filled with pesticide-grade ethyl acetate and covered with plastic snap lids which had previously been lined with aluminum foil. Within 2 hours these bottles were refrigerated at 2°C until extraction.

Extraction of the insecticide and its derivatives from 20 g samples of foliage was accomplished within 15 days following the collection date. The macerated samples were placed in a Waring blender with enough ethyl acetate (pesticide grade) to bring the volume to 150 ml. Using an external rheostat, the sample was blended at gradually increasing speed until it formed a uniform pulp. A Buchner funnel, grade 202 (Reeve Angel) filter paper, and 2 cm pad of anhydrous Na_2SO_4 were used to separate solid plant residues from the extract. Plant solids remaining in the funnel were rinsed with ethyl acetate to ensure total recovery of the residue. The resulting dark-green solution was evaporated to about 10 ml in a 500 ml round-bottom boiling flask on a Buchli Roto vapro R evaporator. This residue was dissolved in 50 ml of pesticide-grade acetonitrile, and was partitioned twice with 25 ml of pesticide-grade hexanes. The polar layers were evaporated to about 20 ml and placed on an activated charcoal column previously rinsed with 50 ml pesticide grade benzene. A 20 mm ID column was used with the following packing: glass wool; 10 g Na_2SO_4 ; mixture of 9 g activated charcoal (BDH), 6 g Celite 503 and 10 g Na_2SO_4 . An electrical vacuum pump providing 270 mm Hg suction was used for elution by 100 ml benzene: ethyl acetate (25:75), followed by 10 ml benzene. The eluate was flushed to a small volume of about 10 ml for analysis. This sample was refrigerated until analysis.

Analysis

Fenithrothion in the extract was analysed by gas-liquid chromatography done on a gas Tracor Model MT 270 equipped with an automatic sampler; Hewlett-Packard, Model 7671A with interface, and an automatic calculator Spectra physics auto lab I, the detector was a FPD system. Operating conditions of the gas chromatograph were: glass column 1.83 m x 0.64 cm, column packing chromasorb W 80/100 mesh, liquid phase 3.6% OV 101, 5.5 wt. The carrier gas was helium with a flow rate of 26 lb/in².

Results

Results of analyses as given in Table I are as ppm of the sample. Concentrations of fenitrothion varied from 0.51 ppm to 0.10 ppm within the sprayed plots and from 0.08 to 0.00 ppm within the control plot. Concentrations obtained after the 1977 spray operation were lower than those observed following the 1976 spray application. In 1976, I obtained an average concentration of 2.5 ppm from 5 samples, these samples were collected in an open area with no canopy cover. However the 1977 collections were from samples selected within the entire branch structure of the tree and this may explain the lower analytical results. The oxygen analogue of fenitrothion, fenitro-oxon, was detected in only two samples taken from the sprayed plots at concentrations of 0.04 and 0.15, whereas no detection was obtained from samples taken from the control plots. Results from both sample areas indicate a persistence of the pesticides throughout the entire sampling period on both the sprayed and control plots with a higher concentration in sprayed plots.

Table I. Fenitrothion residues in balsam fir *Abies balsamea* browse for the 1977 spray program.

Time relative to application (days)	Fenitrothion - ppm	
	Sprayed plot	Control plot
+ 240	0.37	0.05
+ 225	0.27	
+ 210	0.36	0.04
+ 195	0.24	
+ 180	0.38	0.06
+ 165	0.27	
+ 150	0.19	0.00
+ 135	0.26	
+ 120	0.36	0.06
+ 105	0.28	
+ 90	0.24	0.09
+ 75	0.31	
+ 60	0.10	0.04
+ 45	0.31	
+ 30	0.10	0.02
+ 15	0.25	
spray	0.13	0.07
- 1	0.51	0.05
- 15	0.43	0.08
- 30	0.41	0.05
- 45	0.35	
- 60	0.39	0.02
- 75	0.34	
- 90	0.45	0.08
-105	0.39	
-120	0.44	0.08

+ days before spray
- days after spray

Discussion

Oral administration of ¹⁴C fenitrothion at a dose level of 0.5 mg/kg results in absorption of the pesticide and its appearance into the blood and internal organs of rats. After 4 days the concentration in the blood was less than .001 ppm (Miyamoto 1964). Hollingworth and Metcalf (1967) have indicated that the greater part of ³²P and ¹⁴C fenitrothion is excreted in the urine within 24 hours and that excretion is virtually complete within 96 hours. Barber and Nagy (1971) studied the influence of several pesticides on rumen bacteria of deer. With concentrations of 1, 10, 100, and 1000 ppm of fenitrothion, cellulose digestion was respectively 83%, 63%, 25% and 12.6% of the control. After a period of 72 hours all inhibition had ceased. Production of volatile fatty acids was little affected at 1 ppm or 10ppm of the pesticide. At 100 ppm, fenitrothion caused a slight decrease in fatty acid concentrations. Schwartz et al. (1973) studied the effects of certain pesticides on rumen function;

they concluded that fenitrothion did not affect the digestion of dry matter and cell wall constituents.

In relating my findings to the previous work, I can find no evidence to support the hypothesis that a concentration of fenitrothion of the magnitude which I have detected would affect the deer population of this area.

Acknowledgment

This study was conducted under support funds received from Forest Protection Limited and the Conseil de Recherche de l'Université de Moncton, their support is greatly appreciated. I also thank the staff of the Chemistry department, particularly Dr. Victorin Mallet for his assistance with the analytical work. I am also grateful to all who have assisted me during the project.

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THE LIFE CYCLE OF *PLATYMONAS IMPELLUCIDA* MCLACHLAN ET PARKE (PRASINOPHYCEAE) IN CULTURE*

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An asexual life cycle of *Platymonas impellucida* was established in culture. Cells incubated on a light:dark cycle of 18:6 h settled from the medium and attached to the culture vessel 2 hours before initiation of the dark period. Cells divided in darkness, and daughter cells were released from the parent theca shortly thereafter. Thick-walled cysts were formed in abundance after 2 and 8 weeks of incubation in enriched or synthetic seawater respectively. Differences between media of enriched or synthetic seawater with respect to formation of cysts were not resolved. However, attempts to accelerate formation of cysts in the synthetic medium indicated that nutrient deficiency, variation in pH, and slow desiccation had effects. Tolerance of cysts to extremes of temperature and desiccation was no greater than that of motile cells.

Introduction

Life cycles in the Prasinophyceae have received little attention, and, with the exception of one unconfirmed report of sexuality (Gorbunova 1961), only asexual reproduction is known in this class. The life cycle of species of *Platymonas* has been investigated from several aspects. Stewart and Mattox (1975) and Stewart et al. (1974) examined characteristics of cell division and nuclear phases of this genus. Morphological changes in the life history, including formation of cysts and subsequent germination, have been emphasized. Recently the life cycle of an unnamed species of *Platymonas* has been completed (Tanoue & Aruga 1975; Kobara & Hori 1975), with Grant and Vadas (1976) providing additional information for *P. subcordiformis*.

In the present instance I show that the asexual cycle of *P. impellucida* is similar to that described previously for *Platymonas* sp (Tanoue & Aruga 1975), but with certain morphological differences. I have also examined factors leading to formation of cysts, and tolerances of these cysts to temperature and desiccation.

Materials and Methods

Platymonas impellucida McLachlan et Parke was isolated from a sample of water from Puerto Rico (McLachlan & Parke 1967), and this species is No. 161/5 in the Cambridge Culture Collection; cultures are also maintained at the Atlantic Regional Laboratory, Halifax, and at the Marine Biological Laboratory in Plymouth.

An axenic culture was maintained in a synthetic medium, ASP-M, and experimental work was done using this and an enriched seawater medium, SWM-1 (McLachlan 1973). Incubation was in 30 ml of medium contained in 125 ml erlenmeyer flasks capped with shortened glass beakers, the flasks being agitated daily. Cultures were maintained at 25°C; illumination was provided by 40-W, cool-white fluorescent lamps at an intensity of $100\mu\text{E m}^{-2} \text{s}^{-1}$ at the level of the flasks, and the light:dark cycle was 18:6 h.

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Media deficient in nutrients were established by omitting individual compounds from ASP-M. Cells growing exponentially were sedimented by centrifugation and resuspended in medium lacking the indicated compound; the initial concentration of cells was adjusted by dilution to 2×10^4 cells ml^{-1} . Microscopic examination of the cells was made after 3 weeks of incubation.

Medium deficient in carbon was effected by autoclaving ASP-M lacking added bicarbonate in 125-ml screw-capped erlenmeyer flasks; following autoclaving and cooling, the caps were cinched, thus limiting gaseous diffusion into the flask (McLachlan & Craigie 1966); controls were established by the addition of filter-sterilized bicarbonate to each flask, bringing the concentration to 10 mM NaHCO_3 .

Salinity in the synthetic medium was varied by varying the concentrations of NaCl , MgSO_4 , MgCl_2 , CaCl_2 , and KCl while maintaining a constant ratio amongst these salts. Normal salinity of the medium is designated as "X". Other additives were provided at the same concentration independent of salinity.

Effects of pH on formation of cysts were determined in ASP-M containing 10 mM of either glycylglycine or tris buffers to minimize changes in pH. This is twice the normal concentration of buffer, and no effect on rate of growth or final yield of cells resulted from these increases. Cells for inoculation were collected by centrifugation and resuspended into medium of the experimental pH, the initial density of cells being adjusted to 5×10^4 cells ml^{-1} . Concentration of cysts was determined, using a haemocytometer, after 3 weeks of incubation.

Effects of pH on formation of cysts were examined also using membrane filters and membrane-filter pads. Cells for inoculation were centrifuged and resuspended in ASP-M containing 10 mM glycylglycine at the experimental pH; 1 ml of this suspension was gently filtered onto membrane filters (0.45 μm pore size), and these filters were placed into glass petri dishes of 60 mm diameter, some containing discs of filter paper (Whatman No. 1) saturated with the experimental medium. Both procedures were tested with the concentration of cells ranging from 2×10^4 to 5×10^6 cells ml^{-1} , and cells from early exponential, exponential, stationary, and late stationary stages of growth (i.e. 2, 5, 10, and 14 day-old cells respectively). Incubation was in the light under standard conditions, and membrane filters alone became dehydrated within 24 hours and those on filter pads within 3 days; when dry, membranes were examined for viable cells and cysts.

Resistance of motile cells and cysts to temperature and desiccation involved cells grown in SWM-1, 1/10 SWM-1, ASP-M, and 1/10 ASP-M; 1/10 media contained additives of SWM-1 at 0.1 of the specified concentration. Cells from a stage of growth, ranging from 2- to 28- day-old cultures, were collected on membrane filters (0.45 μm) at a concentration of 10^6 cells, and these filters were placed on pads of filter paper saturated with the appropriate medium in glass petri dishes. Two collections, each in triplicate, were made from each age of cells; one group was placed at -2° , 40° , 80°C or in a desiccator with silica gel, and the second group was returned to normal conditions of incubation; after 3 days, microscopic examination was made for the presence of cysts. When cysts were present these filters were transferred to -2° , 40° , 80° , and in a desiccator with silica gel. After 1 hour at the different temperatures or 1 week in the desiccator, filters were removed and placed in tubes containing SWM-1 and incubated under normal conditions; evidence of survival (i.e. presence of motile cells) was determined 2 and 4 weeks after inoculation.

Results

Life Cycle

A light:dark cycle of 18:6 h synchronized cellular division, allowing monitoring of cells during exponential growth. Cells remained motile and single during most of the light period, and after about 16 hours they attached apically to the bottom and sides of the vessel. Once attachment occurred, flagella were discarded. Cell division oc-

curred during darkness resulting in 2 motile daughter cells, and release from the parental theca was during darkness or early in the light period. The actively motile daughter cells mechanically ruptured the parental theca and escaped, and these cells were positively phototactic, gathering at the surface of the medium.

There were always a few cysts in a culture, the percentage being less than 1% during exponential growth, increasing as the culture entered the stationary phase of growth and the cells became older. In stationary phase there was a combination of vegetative cells (single, motile cells, and thecae containing 2 daughter cells) and cells in cyst phase (thecae containing 4 daughter cells, non-motile, spherical cells, and thick-walled cysts).

Cyst formation involved accumulation of starch granules by motile cells, resulting in a more spherical shape. These cells then attached apically, discarded the flagella and formed a thick cell wall. Such cells are referred to as 'immature' cysts, and those which formed short spines protruding randomly from the cell wall are referred to as 'mature' cysts. Both types of cysts germinated in an identical manner. Transfer of cysts to fresh medium resulted in a loss of the granular appearance, followed by division into 4 motile daughter cells. Daughter cells, enclosed in a parental theca, were released from the cyst by a rupture in the wall. Escape from the theca was as described before, there being no difference between these cells and those produced in binary division.

Cyst Formation

In SWM-1 the stationary phase of growth resulted after 7 days of incubation, and during the next 7 days, mature cysts formed with thick walls and short spines. In ASP-M, only a few cells became spherical during the first week of the stationary phase. Although most cells accumulated some starch, these cells never became spherical until at least 6 weeks after inoculation; at this point they had thickened walls devoid of spines.

Acceleration of the formation of cysts was attempted by rendering ASP-M deficient in various components, and these results are summarized in Table 1. Formation of cysts occurred in none of these treatments after 3 weeks of incubation. Although several treatments resulted only in minimal growth, final yield of cells in most being similar to that of the control.

At salinities ranging from 0.1 to 3 times that of the normal salinity of ASP-M, a period of 6 to 8 weeks was required before cysts began to form, although no growth occurred in 0.1 salinity. In all other treatments, the cyst to cell ratio was similar, the concentration depending upon the salinity, and almost all cysts were immature. Formation of mature cysts, therefore, was not related to salinity.

In a range of pH values from 7.0 to 9.5, using both glycylglycine and tris buffers in ASP-M, cysts were present at 1% or less at all pH's after 3 weeks of incubation.

Following dehydration on membrane filters over 24 hours, no viable cells remained, and none had formed cysts. Contrariwise, large numbers of cysts formed on membrane filters on pads of filter paper (Table II); these cysts were immature, lacking spines. This technique resulted in high concentrations of cysts, although it was not always reproducible, and frequently the cells lysed. However, in trials where cysts were formed, percentages were comparable to those in Table II. Concentration of cells and age of cells were varied independently in an attempt to obtain cysts consistently, but none of these combinations was successful.

Cells inoculated into closed flasks containing ASP-M with added 10 mM NaHCO_3 produced after a week of incubation a final yield of cells comparable to that in open flasks. Following a further period of 7 weeks, cells in the open flasks had produced thick-walled cysts, whereas cells in the closed flask were non-viable and had bleached although flagella remained attached to these cells; cysts or cells filled with starch particles were absent.

After 6 weeks on slants of agar (1.5% agar in SWM-1) at 25°C, $25\mu\text{E m}^{-2} \text{ s}^{-1}$, both

Table I. Cell conditions as a function of nutrient deficient media; examined after 3 week in medium lacking indicated compound

Deficient compound	% Cysts	Motile	Attached to flask	Growth	Remarks
NaNO ₃	0	-	-	-	Spherical cells with large conc. starch
NaH ₂ PO ₄	0	-	-	-	Spherical cells
Na ₂ EDTA	0	+	+	+	
FeCl ₃	1	+	+	+	
P-I metals	0	+	+	+	
TMS-II metals	0	+	+	+	
Vitamins	0	+	+	+	
MgSO ₄	0	+	+	+	Deformed chloroplasts
MgCl ₂	0	+	+	+	
CaCl ₂	0	-	-	-	Non-motile with flagella present
Control	0	+	+	+	

Table II. Cyst formation as a function of pH and desiccation

pH	% Cysts	
	Membrane Filter	Membrane filter + filter pad
6.0	-	10
7.0	-	40
7.5	-	95
8.0	-	5
9.0	-	40
10.0	-	40

dead and viable cells were noted. The latter consisted of normal motile, single cells together with non-motile, clumped cells which were spherical and enclosed in at least 2 thecae. Thick-walled cysts were not observed, even after 18 months on agar, but some cells remained viable, and noticeable growth occurred within 4 days when transferred to fresh liquid medium.

Transfer of cells in exponential growth at 25°C to other temperatures did not stimulate formation of cysts. Cells in exponential growth at 20°C were more spherical than those at 25°C, and with an apparently greater number of starch bodies. At 35° or 40°C, cells were spherical, filled with starch, and non-motile. Each theca contained up to 20 spherical cells of different sizes. The diameter of these thecae ranged from 40 to 60 μm, and intrathecal spores ranged in size from 5 to 15 μm which was smaller than the 18 μm average diameter of non-motile cells. Transfer of these cells to 25°C resulted in motile single, flattened cells. Not all spherical cells in enlarged thecae, however, were viable as evidenced by an increased amount of

cellular debris in the medium. Changes in morphology of cells when transferred from 25° to 35°C and then returned to 25°C are illustrated in Figure 1.

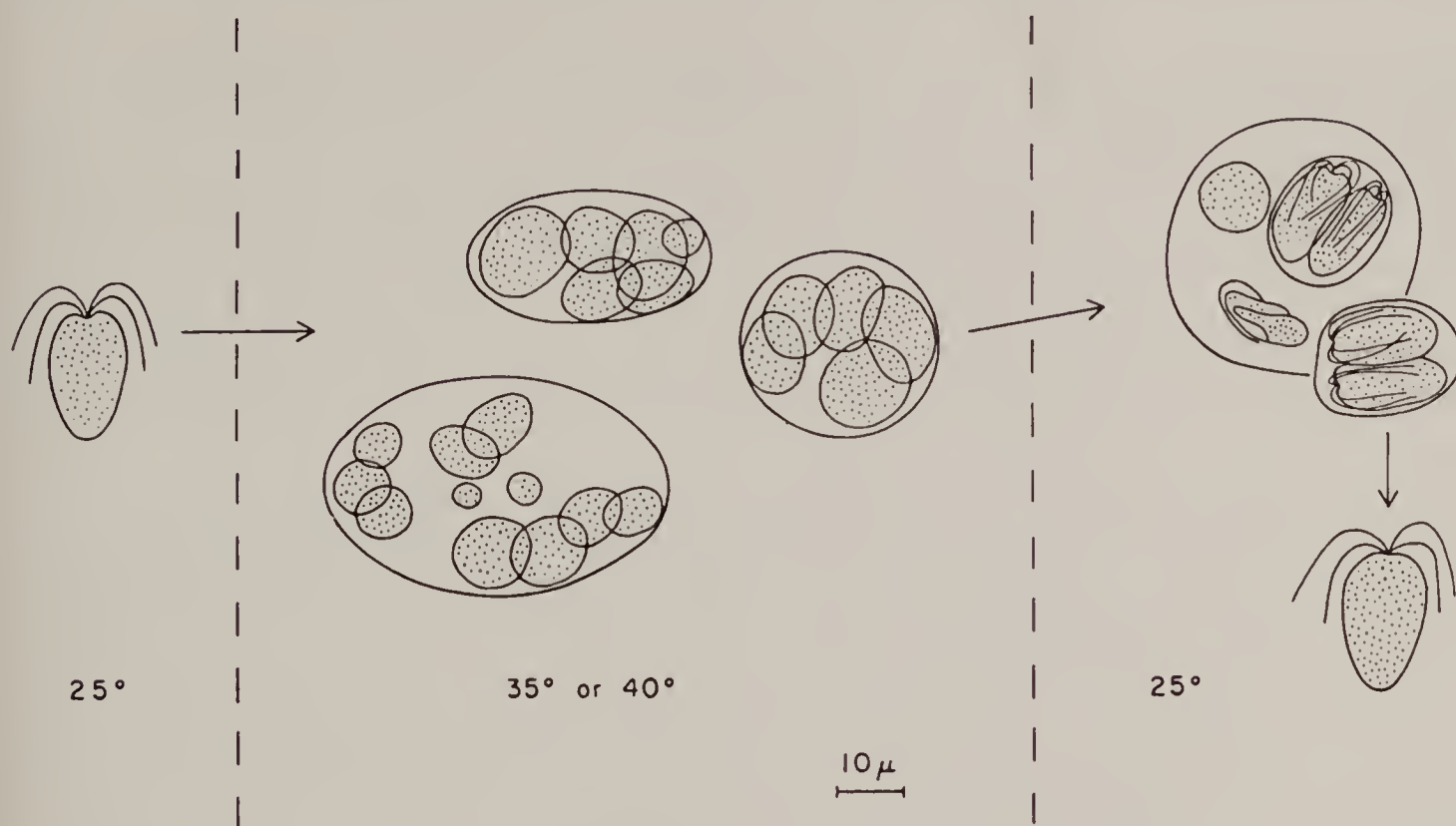


Fig 1. Life cycle of *Platymonas impellucida*

Temperature and Tolerance to Desiccation

The ability of cysts and cells to survive extremes of temperature and desiccation is summarized in Table III. Cells in early exponential growth survived -2°C and 40°C regardless of the medium. Cells from early stationary phase (7 d) and late stationary phase (28 d) of growth were susceptible to all temperatures.

Neither cysts nor cells survived 7 days of desiccation, and in general cysts were no more tolerant of extremes than motile cells.

Discussion

The life cycle of *Platymonas impellucida* resembles that of *Platymonas* sp. (Tanoue & Aruga 1975), but there are several noticeable differences between these 2 cycles. The most obvious being that the 2 daughter cells of *Platymonas* sp were non-motile and attached when they left the parental theca. Further, release from the parent theca was independent of light, although separation of cells was stimulated by light. In contrast, daughter cells of *P. impellucida* formed flagella before separation, and on separation, these cells were actively motile, although retained within the parental theca. The daughter cells swam randomly until rupture of the parental theca resulted. Cellular division in *P. impellucida* usually occurred during darkness with release from the parental theca shortly thereafter, also usually in darkness although some cells were released in the early portion of the light cycle. Other species of *Platymonas* behave similarly to *P. impellucida*. *Platymonas subcordiformis* relies on motile daughter cells to rupture the parental theca (Grant & Vadas 1976) and not the enzymatic method suggested by Tanoue and Aruga (1975) for their species.

Duration in the double-celled condition usually was 2 to 4 hours for *P. impellucida*, and within 2 hours after initiation of the light cycle, all cells were single and motile. Similar observations have been made on *P. tetrathele* (Gooday 1970) and

Table III. Tolerance of motile cells and cysts to temperature (−2°, 40°, 80°C) and desiccation (D) as a function of cell age and medium

Cell age (days)	Medium	Motile cells				Induced cysts			
		−2°	40°	80°	D	−2°	40°	80°	D
2	SWM-1	−	+	−	−	+	−	−	−
	1/10 SWM-1	+	+	−	−	−	−	−	−
	ASP-M	+	+	−	−	−	−	−	−
	1/10 ASP-M	+	+	−	−	+	−	−	−
7	SWM-1	−	−	−	−	−	−	−	−
	1/10 SWM-1	−	−	−	−	−	−	−	−
	ASP-M	−	−	−	−	−	−	−	−
	1/10 ASP-M	−	−	−	−	−	−	−	−
14	SWM-1	+	−	−	−	+	−	−	−
	1/10 SWM-1	−	−	−	−	−	−	−	−
	ASP-M	−	−	−	−	−	−	−	−
	1/10 ASP-M	−	−	−	−	−	−	−	−
21	SWM-1	+	−	−	−	−	−	−	−
	1/10 SWM-1	−	−	−	−	−	−	−	−
	ASP-M	−	−	−	−	−	−	−	−
	1/10 ASP-M	−	−	−	−	−	−	−	−
28	SWM-1	−	−	−	−	−	−	−	−
	1/10 SWM-1	−	−	−	−	−	−	−	−
	ASP-M	−	−	−	−	−	−	−	−
	1/10 ASP-M	−	−	−	−	−	−	−	−

other species of *Platymonas* (Tanoue & Aruga 1975). In all of these species the duration as double cells generally was 2 to 4 hours. However, one species, *P. convolutae*, studied by Gooday (1970), spent most of the light period (20 h) in the double-celled condition, a behavior common to species of *Prasinocladus*.

The fate of flagella differs amongst species. *Platymonas impellucida* behaves as other species of *Platymonas* and *Prasinocladus* studied by Kobara and Hori (1975). Once firmly attached, flagella were discarded and were apparent in the medium. In other species, such as *Platymonas* sp (Tanoue & Aruga 1975), the flagella remain at-

tached to the parental theca even after release of daughter cells. Parental cells of *P. subcordiformis* (Grant & Vadas 1976) released their flagella before attachment. Thus attachment at any point on the parental theca is indicated and not only at the apex, the point where most species of *Platymonas* attach.

The mechanism of attachment is not fully understood. Manton and Parke (1965) reported that species of *Platymonas* and *Prasinocladus* have flagella covered with a thick layer of mucus containing scales. Initial attachment may be a function of this mucilage, holding the cell to the substrate and allowing permanent attachment to occur. This suggestion is not applicable to *P. subcordiformis* which discards its flagella before attachment. However, it has been suggested that *P. subcordiformis* excretes an extracellular adhesive which attaches the parental cell to the substrate, and no metabolic energy is required to maintain this attachment (Grant & Vadas 1976).

The life cycle of many species of Prasinophyceae includes formation of thick-walled, spherical cysts. The production of cysts, most possessing short spines protruding from the surface, is a generic characteristic of species of *Platymonas* (Parke & Manton 1967). Tanoue and Aruga (1975) and Kobara and Hori (1975) have reported on formation of cysts and subsequent germination. Cysts of *Prasinocladus* are the same as for species of *Platymonas* (Kobara & Hori (1975). *Platymonas impellucida* follows the same pattern, with each cyst producing 4 motile daughter cells.

Although formation of cysts apparently is an integral part of the life history of the Prasinophyceae, conditions for formation of cysts are poorly understood. Generally cysts are considered to form under 'unfavorable conditions', although such conditions have not been specified (Peterfi & Manton 1968; Hori & Chihara 1974).

Platymonas impellucida invariably formed a few cysts, even during exponential growth, and after 4 weeks of incubation in ASP-M, about 1% of the cells were as cysts. A large proportion of the cells were as cysts after 6 to 8 weeks, a similar period of time being required by Tanoue and Aruga (1975) to induce cysts in *Platymonas* sp incubated in a synthetic medium. If the medium became deficient in carbon, *P. impellucida* showed no tendency to formation of cysts (i.e. rounding of cells and accumulation of starch), even after 8 weeks. Contrariwise, *P. impellucida* formed large numbers of cysts within 2 weeks if incubation was in SWM-1. Differences between these 2 media, with respect to formation of cysts, were never resolved. There was some indication that the iron component of ASP-M was not entirely adequate for all cellular functions, and reduced chlorophyll a/cell was obtained in this medium. However, rates of growth and final yields of cells were nearly identical for each medium (unpubl. results).

Slow desiccation accompanied with variation in pH stimulated formation of cysts. Minimal numbers of cysts formed around pH 8, the normal pH of seawater (Harvey 1957). Formation of cysts in *P. impellucida* and other species (Tanoue & Aruga 1975) occurred with variation in hydrogen ion concentration and *P. impellucida* also formed cysts at pH values which did not support growth (i.e. pH 9.5 and 10.0) (unpubl. results), suggesting that cysts function as a protective mechanism. Modification of pH without desiccation or modification of pH with rapid desiccation failed to induce formation of cysts and in the latter case, no cells survived.

Low tolerance of extremes in temperature and long periods of desiccation casts doubt on the ecological significance of cysts. Although in formation of cysts, cells underwent a 3-day period of desiccation, they were less tolerant of extremes in temperature than were motile cells. None of the cells or cysts withstood 7 days of desiccation over silica gel. The observation that cysts are not more resistant to extremes of temperature and desiccation than motile cells is not unusual. Evans (1958; 1959) suggested that in freshwaters, the ability to survive desiccation and heat was not related to the ability to form cysts. Belcher (1970) investigated effects of temperature and desiccation in 11 species of freshwater Prasinophyceae, and was able to show increased tolerance of cysts over the motile cells in only 7 species.

Considering cysts of *P. impellucida* as a protective mechanism has some appeal. General depletion of nutrients, variation of pH from the norm, and increase in salinity, all induced formation of cysts. Increases in temperature, which induced formation of cysts in other species of *Platymonas* and *Prasinocladus* (Kobara & Hori 1975), did not stimulate formation of cysts in *P. impellucida*. Whether cysts of species of marine Prasinophyceae are more resistant to drought and temperature than motile cells requires additional study. However, conditions for formation of cysts in *P. impellucida* indicate that cysts may have ecological advantage.

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LES ALGUES MARINES BENTHIQUES DES ILES-DE-LA-MADELEINE (QUÉBEC)

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Cet inventaire des algues marines benthiques des Iles-de-la-Madeleine comprend 101 espèces, sous-espèces, et variétés se répartissant comme suit: 19 Chlorophyceae, 37 Phaeophyceae et 45 Rhodophyceae. Les localités, les mois de récolte, les profondeurs d'échantillonnage ainsi que certains détails phénologiques sont colligés. Une description sommaire des conditions physiques et chimiques qui prévalent dans les eaux du plateau madelinot est aussi incluse.

The list of marine benthic algae of the Magdalen Islands comprises 101 species, subspecies, and varieties consisting of 19 Chlorophyceae, 37 Phaeophyceae and 45 Rhodophyceae. The locations, month(s) of collection, depth and phenological details for some species are noted. A brief summary of the physical and chemical conditions prevailing in the waters of the Magdalinien plateau is included.

Introduction

L'inventaire des algues marines benthiques de l'est du Canada a déjà fait l'objet d'une première publication par South et Cardinal (1970), suivie d'une révision par South (1976). Les algues de l'estuaire du Saint-Laurent ont été recensées par Cardinal et Villalard (1971) et celles de la baie des Chaleurs et de la Baie de Gaspé par Cardinal (1967a; b; c). Pour une liste détaillée des principaux travaux relatifs aux algues benthiques des ces régions québécoises, nous référons le lecteur à ces publications.

Vu le petit nombre de publications sur les algues du Québec, les auteurs ont cru utile de présenter, à la suite des travaux de De Sève et al. (1978) et de ceux de Cardinal (1967d; 1968), un inventaire des algues marines benthiques des Iles-de-la-Madeleine. Ces travaux, publiés dans des rapports à circulation limitée, avaient pour but principal d'évaluer le potentiel de mariculture des algues aux Iles-de-la-Madeleine. L'inventaire qui figure ci-après porte sur les deux principaux types d'habitat des Iles-de-la-Madeleine, soit les lagunes (De Sève et al. 1978) qui occupent 38.8% de la superficie des îles, et les rivages et fonds marins infralittoraux à l'extérieur des lagunes (Cardinal 1967d; 1968). L'inventaire des algues résulte de 60 échantillonnages en plongée (De Sève et al. 1978) et de 95 échantillonnages, principalement par dragage, effectués lors de l'expédition de l'Akpatok en 1966 (Cardinal 1967d; 1968).

Région Étudiée

L'archipel des Iles-de-la-Madeleine est situé approximativement au centre du golfe Saint-Laurent, soit entre le 47^e et 48^e parallèle de latitude Nord et le 61^e et 62^e parallèle de longitude Ouest. Il est constitué d'un groupe de quinze noyaux rocheux dont les sept principaux sont reliés entre eux par de longs cordons sablonneux délimitant des lagunes (Tiphane 1976). Les trois principales lagunes sont celles de la Grande-Entrée, du Havre-aux-Maisons et du Havre-aux-Basques (Fig 1). Les deux premières communiquent directement avec la mer par de larges chenaux assurant ainsi une circulation efficace d'eau de mer contrairement à celle du Havre-aux-Basques, où les échanges sont très réduits.

Le climat est maritime et les températures moyennes de l'air sont de 10°C pour les mois de juin, juillet et août (Tiphane 1976). Les profondeurs du plateau madelinot sont faibles (Steven 1974) et l'influence de la marée est atténuée dans cette région avec des amplitudes maximales de 0.91 m et minimales de 0.05 m (Auclair 1977). Les fonds marins sont composés de sable et de rocs, alors que les fonds lagunaires sont surtout composés de sable, fin (0.25 m) à faible profondeur et très fin (0.09 mm) à plus grande profondeur (Tiphane 1976).

D'une manière générale, les conditions physiques des eaux lagunaires sont voisines de celles de l'eau de mer, sauf à la lagune du Havre-aux-Basques, tandis que les conditions chimiques accusent de plus grandes variations.

En été, la salinité moyenne de l'eau de mer est de 29.5-29.8‰ (Tiphane 1976). Elle est légèrement inférieure aux salinités moyennes des lagunes du Havre-aux-Maisons (30.8‰) et de la Grande-Entrée (31.2‰) telles que rapportées par De Sève et al. (1978). Ces deux lagunes possèdent une structure homohaline puisque, d'une station à l'autre et aux diverses profondeurs, la salinité varie peu due aux échanges efficaces d'eau dans les lagunes ainsi qu'avec la mer. Par contre, à la lagune du Havre-aux-Basques, la salinité moyenne est faible (19.2‰) et peut atteindre 10.6‰ à certains endroits (De Sève et al. 1978). Ceci suppose un faible échange d'eau avec la mer ainsi qu'un important apport d'eau douce.

La température des eaux du plateau madelinot augmente graduellement à partir du mois de juin pour atteindre son maximum au mois d'août. Dans l'eau de mer, Tiphane (1976) rapporte des températures moyennes de surface de 15°C et 17°C respectivement pour les mois de juillet et août. Dans les lagunes, les températures sont légèrement plus élevées avec des moyennes de 15°C en juin, 17°C en juillet et 20°C en août (De Sève et al. 1978). En outre, les lagunes présentent une homogénéité thermique qui résulte, comme l'homogénéité haline, du mouvement vertical des eaux gouverné par la turbulence due à la faible profondeur des lagunes et à la fréquence des vents (Auclair 1977).

Les concentrations en sels nutritifs des eaux de surface (0-10 m) des Iles-de-la-Madeleine sont généralement plus élevées dans les lagunes que dans la mer. En effet, Auclair (1977) rapporte des concentrations de nitrates supérieures à 0.50 mg-at NO₃-N/l pour les mois de juillet et août dans les lagunes alors que dans l'eau de mer, en surface, elles ne sont que de 0.04-0.13 mg-at NO₃-N/l (Bulleid & Stevens 1972). Cependant, d'après Auclair (1977), ces concentrations élevées seraient d'origine extérieure aux lagunes. Ces concentrations en nitrates demeurent toutefois faibles et pourraient être limitantes faute d'autres sources azotées (Auclair 1977). Les concentrations en phosphates des eaux lagunaires sont également plus élevées que celles de l'eau de mer; pour les mois de juin, juillet, et août les concentrations moyennes dans les lagunes sont de 1.00 mg-at PO₄-P/l (Auclair 1977) et de 0.19-0.25 mg-at PO₄-P/l seulement dans la mer (Bulleid & Steven 1972). Selon Auclair (1977), les concentrations élevées de phosphates dans les eaux lagunaires pourraient s'expliquer par l'abondance de *Zostera marina*. En effet, il semble que cette angiosperme aquatique peut puiser le phosphore des sédiments et le libérer par les feuilles sous forme d'orthophosphates (McRoy et al. 1972).

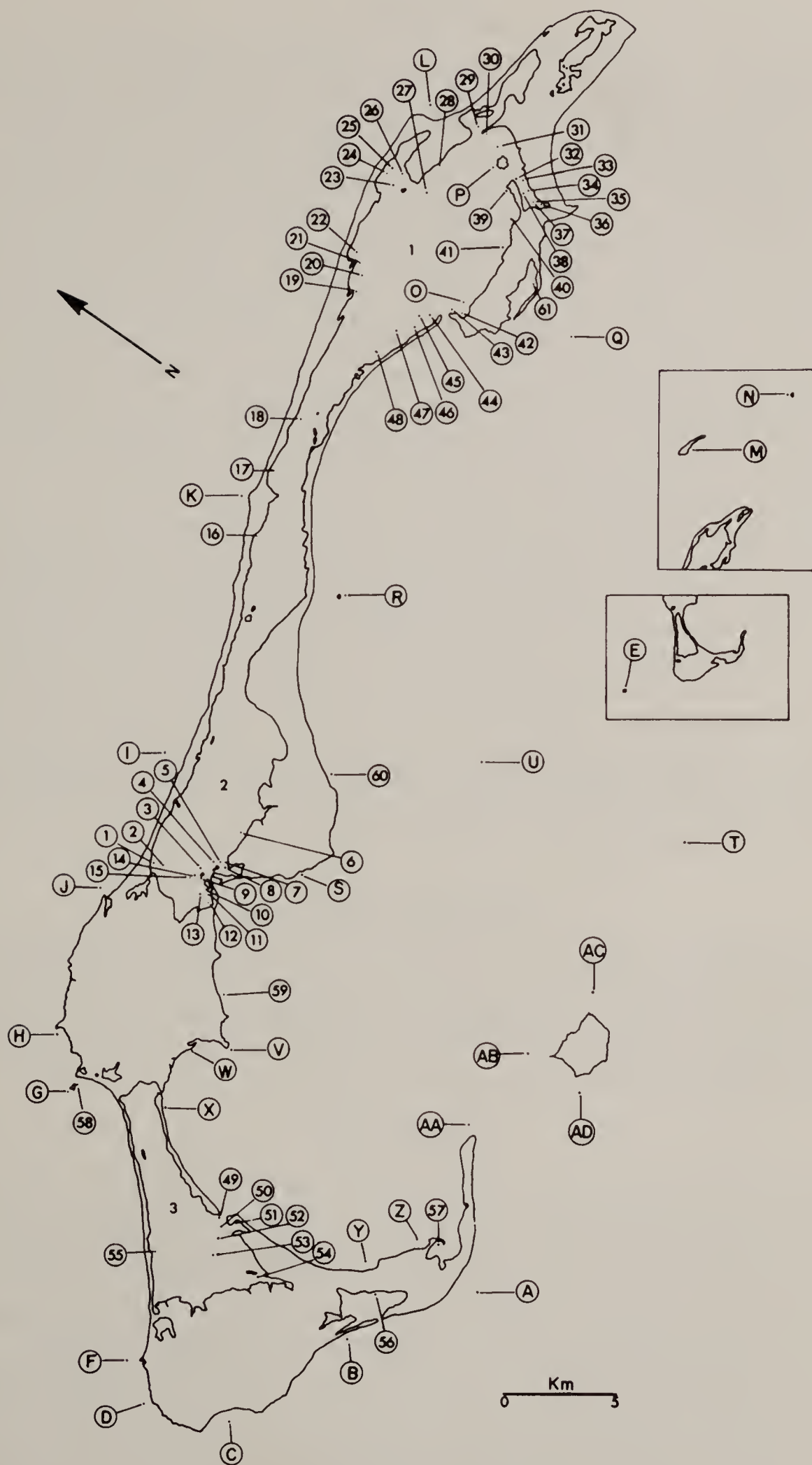


Fig 1. Carte des Iles-de-la-Madeleine indiquant les trois principales lagunes, 1: lagune de la Grande-Entrée, 2: lagune du Havre-aux-Maisons et 3: lagune du Havre-aux-Basques. Les localités échantillonnées par De Sève et al. (1978) sont indiquées par les chiffres encadrés 1 à 60, celles échantillonnées par Cardinal (1967d; 1968) sont indiquées par les lettres encadrées A à AD.

Résultats

La présente liste (Tableau I) comprend les espèces identifiées par De Sève et al. (1978) et celles identifiées par Cardinal (1967a, 1968). Les 101 espèces mentionnées* se répartissent comme suit: 19 Chlorophyceae, 37 Phaeophyceae et 45 Rhodophyceae. Le nombre total d'espèces à l'extérieur des lagunes est de 80, comparativement à 50 dans les lagunes du Havre-aux-Maisons et de la Grande-Entrée. La lagune du Havre-aux-Basques ne compte que 7 espèces et ceci pourrait s'expliquer par sa faible salinité ainsi que par le peu d'échange avec la mer. Des espèces identifiées, 18 sont présentes seulement dans les lagunes et 45 seulement à l'extérieur des lagunes. Ceci semble indiquer que la flore des lagunes est passablement différente de celle à l'extérieur des lagunes. Le rapport R/P (Rhodophyceae/Phaeophyceae) est de 1.22 pour l'ensemble des algues identifiées. Ce rapport R/P est semblable à celui de l'ensemble de l'est du Canada 1.23, calculé d'après South et Cardinal (1970). Il est cependant supérieur à celui (0.7) de la côte du Labrador (Wilce 1959) et à celui (0.89) de l'estuaire du Saint-Laurent (Cardinal & Villalard 1971).

La liste des algues benthiques des Iles-de-la-Madeleine qui suit (Tableau I), est accompagnée d'un certain nombre de données. Dans une première colonne, les espèces d'algues sont énumérées selon l'ordre systématique proposé par South (1976). La deuxième colonne indique les localités où les espèces ont été échantillonnées. Ces localités sont numérotées de 1 à 60 pour les stations échantillonnées par De Sève et al. (1978) principalement dans les lagunes, et de A à AD pour les stations échantillonnées par l'Akpatok (Cardinal 1967d; 1968) surtout à l'extérieur des lagunes. Dans la colonne suivante, les mois de récolte sont indiqués par les chiffres 6, 7 et 8 correspondant respectivement aux mois de juin, juillet, et août, et certains détails phénologiques sont notés lorsqu'il y a lieu. La dernière colonne indique les profondeurs d'échantillonnage.

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* Le groupe des Cyanophyceae a été omis de la liste en raison du petit nombre d'espèces identifiées.

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Tableau I. Liste des algues marines benthiques des Iles-de-la-Madeleine

RHODOPHYTA			
FLORIDEOPHYCEAE			
	Localités	Mois de récolte et phénologie*	Profondeur (m)
NEMALIALES			
ACROCHAETIACEAE			
<i>Audouinella daviesii</i> (Dillw.) Woelk. ^x	J	7	3-12
<i>Audouinella spetsbergensis</i> (Kjellm.) Woelk. ^x	D,E,G,I,J,R	7,T	6-21
<i>Colaconema secundata</i> (Lyngb.) Woelk.	E,O,P	7	1-21
BONNEMAISONIACEAE			
<i>Bonnemaisonia hamifera</i> Hariot	+		
GIGARTINALES			
SOLIERIACEAE			
<i>Turnerella pennyi</i> (Harv.) Schm. ^x	D,E	7	24-27
RHODOPHYLLIDACEAE			
<i>Cystoclonium purpureum</i> (Huds.) Batt.	E,G,J,M,O,R, X,AA,8,10,13,15, 24,34,35,45,58, 59	6,7,8,T	0-21

	Localités	Mois de récolte et phénologie	Profondeur (m)
GRACILARIACEAE			
<i>Gracilaria tikvahiae</i> McLachlan [†]	11,24,26,27,31, 34,42	6,7,8	1-1.5
PHYLLOPHORACEAE			
<i>Ahnfeltia plicata</i> (Huds.) Fries	M,X,AA,1-3,5,6, 8-15,17,18,20,22- 24,26,27,34,42, 44,47,59,60	6,7,8	0-3
<i>Phyllophora pseudoceranoides</i> (Gmelin) ^x			
Newr. et A. Taylor	E,J	7	10.5-21
<i>Phyllophora truncata</i> (Pallas) A.Zin. ^x	J,Q,R.	7	6-18
GIGARTINACEAE			
<i>Chondrus crispus</i> Stackh.	E,G,H,J,K,L,M, N,P,R,S,Y,AA, 1-15,17,19,20,23- 28,30,31,34,35, 37,45,56,58,59	6,7,8,T	0-21
POLYIDEACEAE			
<i>Polyides rotundus</i> (Huds.) Grev.	J,M,1,10,11,13, 15,20,27,32,34, 35,59	6,7,8	0-4.5
CRYPTONEMIALES			
PEYSSONNELIACEAE			
<i>Peyssonnelia rosenvingii</i> Schm. in Rosenv. ^x	D	7	12-15
<i>Rhodophysema georgii</i> Batt. [†]	O,P	7,T	10-12
HILDENBRANDIACEAE			
<i>Hildenbrandia rubra</i> (Sommerf.) Menegh. ^x	AD	7,T	24
CORALLINACEAE			
<i>Clathromorphum circumscriptum</i> (Strömf.) Fosl. ^x	G,J,N.	7	9-21
<i>Clathromorphum compactum</i> (Kjellm.) Fosl.	E,G,J,N.T	7	0-18
<i>Corallina officinalis</i> L.	D,E,G,H,J,M,N, T,U,V,AA,AB, AD,10,14,17,18, 23,28,34,45,60	6,7,8	0-18
<i>Lithothamnium glaciale</i> Kjellm. ^x	D,E,F,G,H,I, J,N,U,AB	7	0-24
<i>Lithothamnium lemoineae</i> Adey ^x	G	7	3-8
<i>Melobesia farinosa</i> Lamour. [†]	P	7	1-4.5
<i>Melobesia lejolissii</i> Rosan.	+		
KALLYMENIACEAE			
<i>Callophyllis cristata</i> (C.Ag.) Kütz. ^x	D,E,H,J,R,T	7	3-24

	Localités	Mois de récolte et phénologie	Profondeur (m)
CHOREOCOLACACEAE			
<i>Harveyella mirabilis</i> (Reinsch) Reinke ^x	A,E,F,G,Y	7,T,F	0-21
PALMARIALES			
PALMARIACEAE			
<i>Halosaccion ramentaceum</i> (L.) J.Ag. ^x	G,L,Y,AA,AC,59	7	0-9
<i>Palmaria palmata</i> (L.) O. Kuntze	A,B,F,G,H,J,K,L, M,Q,R,S,T,V,Y, AB,AC,AD,14, 59,60	7	0-21
CERAMIALES			
CERAMIACEAE			
<i>Antithamnion cruciatum</i> (C.Ag.) Näg. ^x	59	7	1.5
<i>Ceramium deslongchampii</i> var. <i>hooperi</i> (Harv.) Taylor [†]	6,16,18,35,42	6,7,8	0-1
<i>Ceramium diaphanum</i> (Lightf.) Roth [†]	P	7	1-4.5
<i>Ceramium elegans</i> (Ducluz.) C.Ag.	J,P	7	1-5
<i>Ceramium rubrum</i> (Huds.) C.Ag.	D,E,G,J,K,O,P, V,X,Y,Z,AA,AB, AC,19,23,25,29, 33,36,40,41,45, 58,59,60	7,8	0-1.5
<i>Ptilota serrata</i> Kütz.	A,B,D,E,G,H,I,J, K,M,N,Q,R,S, V,Y,Z,AA,AD, AC,2,14,59,60	6,7,8,T	0-30
DELESSERIACEAE			
<i>Membranoptera alata</i> (Huds.) Stackh. ^x	E,J,L,R	7	1.5-24
<i>Pantoneura baerii</i> (Post. et Rupr.) Kylin ^x	I	7	9-18
<i>Phycodrys rubens</i> (L.) Batt. ^x	A,B,D,E,F,H,I, J,N,R,S,AC,AD	7	3-30
RHODOMELACEAE			
<i>Polysiphonia flexicaulis</i> (Harv.) Coll.	X,AD,8,10,17,33, 35,61	6,7,8,T,F,M	0-10.6
<i>Polysiphonia harveyi</i> Bailey ^x	J	7,M	0
<i>Polysiphonia nigra</i> (Huds.) Batt.	0,2,5,6,7,10,11, 14,15,21,23,27, 34,42,44,49-53, 58,59	6,7,8	3
<i>Polysiphonia nigrescens</i> (Huds.) Grev. [†]	13,28	7,8	0-1
<i>Polysiphonia urceolata</i> (Lightf.) ex. Dillw. Grev. ^x	A,D,E,F,G,H,I, J,L,T,U,AB,AC	7,T,F	4.5-21
<i>Rhodomela confervoides</i> (Huds.) Silva	A,E,F,V,AC,20, 23,28,34,60	7,8,T	0-21

	Localités	Mois de récolte et phénologie	Profondeur (m)
BANGIOPHYCEAE PORPHYRIDIALES			
GONIOTRICHACEAE			
<i>Goniotrichum alsidii</i> (Zanard.) Howe	G,K,O,P,AB,10	7	0-9
BANGIALES			
ERYTHROPELTIDACEAE			
<i>Erythrotrichia carnea</i> (Dillw.) J. Ag.	E,J,K,O,P,X	7	3-21
<i>Porphyropsis coccinea</i> (J. Ag. ex Aresch.) Rosenv. ^x	R	7	6
BANGIACEAE			
<i>Porphyra miniata</i> (C. Ag.) C. Ag. ^x	G	7	3-7.6
PHAEOPHYTA PHAEOPHYCEAE ECTOCARPALES			
ECTOCARPACEAE			
<i>Ectocarpus fasciculatus</i> Harv. var. <i>fasciculatus</i> ^x	J	7	7.6-18
<i>Ectocarpus siliculosus</i> (Dillw.) Lyngb.	D,E,F,G,J,L,O,P, S,T,W,AA,AB, AC,48	7,8,S	0-21
<i>Feldmannia paradoxa</i> (Mont.) Hamel ^x	G	7	9
<i>Giffordia intermedia</i> (Rosenv.) S. Lund [†]	0	7	3
<i>Giffordia ovata</i> (Kjellm.) Kylin ^x	A,D,E,G,J	7	9-21
<i>Pilayella littoralis</i> (L.) Kjellm.	A,G,I,K,P,X	7	0-9
RALFSIACEAE			
<i>Ralfsia verrucosa</i> (Aresch.) J. Ag. ^x	Z,AB	7	0-9
MYRIONEMATACEAE			
<i>Myrionema magnusii</i> (Sauv.) Lois. [†]	P	7	1-4.5
ELACHISTACEAE			
<i>Halothrix lumbricalis</i> (Kütz.) Reinke [†]	0	7	3
<i>Leptonematella fasciculata</i> (Reinke) Silva	D,E,G,J,P,T	7	0-24
CHORDARIACEAE			
<i>Chordaria flagelliformis</i> (O. F. Müll.) C. Ag.	A,B,D,E,F,G,H, I,J,K,L,M,O,P, R,S,V,W,X,Y, AA,AB,AC,AD, 3,12,14	6,7	0-21
<i>Cladosiphon zosterae</i> (J. Ag.) Kylin [†]	2,4,5,10,15,25,27 -29,32,52,53	6,7,8	0-2
<i>Eudesme virescens</i> (Carm. ex. Harv. in Hook.) J. Ag. ^x	AB	7	0-6

	Localités	Mois de récolte et phénologie	Profondeur (m)
STRIARIACEAE			
<i>Isthmoplea sphaerophora</i> (Charm.) ex Harv. in Hook. Kjellm. ^x	F	7,S	0-4.5
<i>Stictyosiphon onustus</i> (Kütz.) South	G,O,P	7	3-9
<i>Stictyosiphon tortilis</i> (Rupr.) Reinke [^]	D,G	7	0-9
PUNCTARIACEAE			
<i>Desmotrichum undulatum</i> (J.Ag.) Reinke	J,O,W	7	0-18
<i>Punctaria latifolia</i> Grev. [^]	F,AB,AC,58	7,S	0-7.6
DICTYOSIPHONACEAE			
<i>Dictyosiphon foeniculaceus</i> (Huds.) Grev.	G,H,J,K,L,M,N, O,S,X,Y,AA,AB, AC,52,57,60	7,8	0-21
SCYTOSIPHONACEAE			
<i>Petalonia fascia</i> (O.F. Müll) O. Kuntze	F,M,AA,AB,10, 14	7	0-6
DESMARESTIALES			
DESMARESTIACEAE			
<i>Desmarestia aculeata</i> (L.) Lamour.	A,D,G,H,J,R,X, AB,AC,AD,14, 15,59,60	6,7,8	0-18
<i>Desmarestia viridis</i> (O.F. Müll.) Lamour. [^]	D,E,F,H,I,J, M,N,R,T,V,Y, AB,AC,AD,58	7	3-21
LAMINARIALES			
CHORDACEAE			
<i>Chorda filum</i> (L.) Stackh.	D,E,F,G,J,K, O,S,X,AB,AC, AD,10,12,14,28, 29,37,45,48,60	7,8	0-10.5
<i>Chorda tomentosa</i> Lyngb. [^]	AB,AC	7,S	0-7.6
LAMINARIACEAE			
<i>Agarum cribosum</i> (Mert.) Bory [^]	A,B,D,E,F,G,H, I,J,N,R,Z,AC,60	7,8	3-24
<i>Laminaria digitata</i> (Huds.) Lamour. [^]	F,H,J,58	7,8	4.5-15
<i>Laminaria longicuris</i> Pyl.	A,F,H.M.S,V,J,8, 14,58-61	6,7,8	0-12
<i>Laminaria saccharina</i> (L.) Lamour.	D,E,L,M,O,P,Q, R,V,X,Y,AB,AD, 10,14,15,59	6,7,8	0-12
<i>Saccorhiza dermatodea</i> (Pyl.) J.Ag.	D,E,G,H,L,O,Q, R,T,AB,AC,AD	7	0-18

	Localités	Mois de récolte et phénologie	Profondeur (m)
TILOPTERIDALES			
TILOPTERIDACEAE			
<i>Haplospora globosa</i> Kjellm.	+		
SPHACELARIALES			
SPHACELARIACEAE			
<i>Sphacelaria furcigera</i> Kütz ^x	J	7	10-12
<i>Sphacelaria plumosa</i> Lyngb. ^x	J,Q	7	6-18
FUCALES			
FUCACEAE			
<i>Ascophyllum nodosum</i> (L.) Le Jol.	F,H,1,8,14,56,60	6,7,8	0-4.5
<i>Fucus distichus</i> subsp. <i>edentatus</i> (Pyl.) Powell [†]	3,4,8,12,14,15, 56,57	6,7,8	0-1.5
<i>Fucus distichus</i> subsp. <i>evanescens</i> (C.Ag.) Powell ^x	M	7	0-1.5
<i>Fucus spiralis</i> L.	1,7,10,12,28,60	6,7,8	0-1
<i>Fucus vesiculosus</i> L.	1,6-8,10,30,35, 56,58,60	6,7,8	0-1,5
CHLOROPHYTA			
CHLOROPHYCEAE			
ULOTRICHALES			
ACROSIPHONIACEAE			
<i>Spongomorpha arcta</i> (Dillw.) (Kütz.) ^x	F,J,X,AC,60	7,8	0-12
ULVALES			
ULVACEAE			
<i>Enteromorpha compressa</i> (L.) Grev. [†]	51,52,55,56	8	0-1.5
<i>Enteromorpha flexuosa</i> subsp. ^x <i>biflagellata</i> (Bliding) Bliding	C	7	12
<i>Enteromorpha flexuosa</i> subsp. <i>pilifera</i> (Kütz.) Bliding	+		
<i>Enteromorpha intestinalis</i> (L.) Link [†]	49,55	8	0-1.5
<i>Enteromorpha linza</i> (L.) J.Ag. [†]	6	6	1
<i>Enteromorpha torta</i> (Mert. in. Jürg.) Reinb.	+		
<i>Percursaria percursea</i> (C.Ag.) Rosenv. [†]	1,6,18,19,42	6,7,8	0-1
<i>Ulva lactuca</i> L.	F,O,P,W,X, Y,6,8,10,12,23, 35,50,59,60,61	6,7,8	0-6
<i>Ulvaria obscura</i> var. <i>blyttii</i> (Aresch.) Bliding	A,H,K,O,P,W, X,AD	7	0-11

CHAETOPHORALES

CHAETOPHORACEAE

<i>Bolbocoleon piliferum</i> N. Pringsh. ^x	AB	7	3
<i>Ectochaete wittrockii</i> (Wille) Kylin ^x	AD	7	0-6
<i>Entocladia flustrae</i> (Reinke) Batt. ^x	A	7	12

CLADOPHORALES

CLADOPHORACEAE

Chaetomorpha cannabina (Aresch.)

Kjellm.

X,AA,51,54 7,8 0-3

Chaetomorpha capillaris (Kütz.) Børg.^x

G,AB,AD 7 0-10.5

Chaetomorpha linum (O.F. Müll.) Kütz.K,5,7,10-13,33, 7,8 0-1.5
44*Chaetomorpha melagonium* (Web. etMohr.) Kütz.^x

J,AA 7 1.5-12

Cladophora albida (Huds.) Kütz.[†]

6,56 6 1

Cladophora sericea (Huds.) Kütz.[†]

4,13,14 6,7,8 0-1

Rhizoclonium riparium (Roth) Harv.

E,6,9 6,7 0-21

* Les symboles utilisés dans cette colonne correspondent à: S(sporocyste uniloculaire), F(plantes femelles), M(plantes mâles), T(tétraspores).

+ Localité inconnue

x Espèce d'algue présente seulement à l'extérieur des lagunes

† Espèce d'algue présente seulement dans les lagunes.



PROCEEDINGS OF MEETINGS 1978-1979

HALIFAX CHAPTER

1st Ordinary Meeting, 2nd October 1978

"Geological and political implications of geothermal energy in the Azores", F. Aumento, Dalhousie University.

2nd Ordinary Meeting, 6th November 1978

"Computer based search and retrieval systems of the scientific literature", J.E. Sutherland, Bedford Institute of Oceanography.

3rd Ordinary Meeting, 4th December 1978

"Distances, area, and π ", A.R. Thompson, Dalhousie University.

4th Ordinary Meeting, 17 January 1979

"Highway survival - forced evolution", C.R. Baird, Nova Scotia Technical College.

5th Ordinary Meeting, 5th February 1979

"Marine archeology - another perspective in the history of the Atlantic provinces", J.A. Carter, Martec Ltd., Halifax.

6th Ordinary Meeting, 5th March 1979

"From the diaries of a lichen hunter", W.S.G. Maass, Atlantic Regional Laboratory.

Extraordinary Meeting, 16 March 1979

(3rd A.C. Neish Memorial Lecture) "The evolutionary basis for religious belief: Marx's takeover bid for Darwinian Sociobiology", F.R Hayes, Dalhousie University.

7th Ordinary Meeting, 2nd April 1979 (jointly with the Valley Chapter, Dalhousie University)

"A modern tale of two towns", A. Taylor, Atlantic Regional Laboratory.

VALLEY CHAPTER

1st Ordinary Meeting, 5th March 1979

"Maintaining plant resistance to disease", M. G. Anderson, Kentville Research Station.

"Carbon dioxide enrichment of greenhouse crops - some physiological considerations", P.R. Hicklenton, Kentville Research Station.

2nd Ordinary Meeting, 26 March 1979

"Alcoholism - treatment and recovery", D.B. Carruthers and G. Wilson, Miller Hospital, Kentville.

3rd Ordinary Meeting, 2nd April 1979 (jointly with the Halifax Chapter, Dalhousie University)

"A modern tale of two towns", A. Taylor, Atlantic Regional Laboratory.

THE PRESIDENT'S REPORT

During 1978-79 the Institute held 2 lecture series, 1 in Halifax and a shorter series in the Annapolis Valley. The successful series were arranged by B.L. Blackford, A.Y. MacLean, and A. Taylor in Halifax and by R.E. Olsen in the Annapolis Valley. The Institute is indebted to them for obtaining interesting and informative speakers whose topics ranged from lichen taxonomy to automobile evolution. The Institute is also indebted to the Nova Scotia Museum of Science, in whose auditorium the Halifax lectures were held. It is a distinct advantage to have a fixed location for a lecture series and we are fortunate to have so hospitable a host.

The disappointment of the year was the cancellation of a special meeting which Dr. A. Hanson, director of Dalhousie University's Institute for Resources and Environmental Studies had agreed to co-sponsor with our Institute. The speaker, Richard Golab, director of the Center for Short-Lived Phenomena, was himself the victim of a short-lived phenomenon. He spent a weary day at the Boston airport until finally his delayed flight to Halifax was cancelled because of a sleet storm. His Center has studied sonic booms, oil spills, and ship sinkings off the Nova Scotian coast and it is hoped that the Institute soon will find an occasion to invite him again under pleasanter circumstances.

A far more successful event was the 3rd A.C. Neish Memorial Lecture co-sponsored by the A.C. Neish Memorial Trust and the Institute. Dr. F. Ronald Hayes was the speaker and discussed the topic "The Evolutionary Basis for Religious Belief: Marx's Takeover Bid for Darwinian Sociobiology". The lecture is included in this issue of the PROCEEDINGS. Following the meeting a reception was held for Mrs. A.C. Neish and Dr. Hayes in the Faculty Club of Dalhousie University.

Under the direction of the editor, J. McLachlan, and the editorial board (H.B.S. Cooke, I.A. McLaren, A. Taylor, P.J. Wangersky, and S.P. Vander Kloet) all parts (1 to 4) of volume 28 of the PROCEEDINGS have been published. The original papers presented in the PROCEEDINGS emphasize and continue a tradition of contributing to our knowledge of the natural history of the Maritimes area. The editor and the board are to be commended for their excellent work. It is hoped that membership fees, research grants, and submitted papers from the membership will continue to support the PROCEEDINGS with the money and materials necessary to maintain the new vigor editor J. McLachlan has injected into the publishing activities of the Institute.

At the final meeting of this year's Council, it was agreed to accept an Atlantic Geoscience Society proposal for a joint meeting in the autumn at which the speaker would be Dr. J. Ostrom, a leading dinosaur researcher. Possibly the new Council should consider more joint or co-sponsored meetings with other scientific societies or organizations in the area. It would provide a better audience for the speaker and would introduce more people to the broader activities of the Institute and encourage membership.

Finally I would like to thank the members of the Council whose help and support has made my work simple. In particular, I wish to express my appreciation to our secretary, Klaus Hellenbrand, who has included coffee making with his secretarial duties; to our treasurer, John van der Meer, who has the onerous task of keeping the membership records in order and whose books balance!; to our editor, Jack McLachlan, whose achievements I have mentioned; and to our librarian Evelyn Campbell, who for many years has given generously of her free time in looking after the publications of the Institute and the many library exchanges.

My best wishes go to the new president, the council and the membership for a successful 1979-80 season.

Paul H. Odense

INSTRUCTIONS TO AUTHORS

The *Proceedings of the Nova Scotian Institute of Science* publishes the proceedings of the Institute and original articles, including notes, pertaining to the natural sciences of the Atlantic Provinces, especially in biology and geology. Manuscripts may be either in English or French, and acceptance for publication is based on recommendations of referees.

Manuscripts should be typewritten, double-spaced on white paper 21.5 by 28 cm (8.5 by 11 in) with margins of 4 cm (1.5 in). Underline only material to be set in italics, and use capital letters only when letter or words should appear in capitals in the printed paper. Layout and style should follow that used in this volume. The original copy and one duplicate are required. Each page of the manuscript should be numbered, the first page carrying only the title, authors' names and affiliations, and any necessary footnotes.

Spelling should follow that of **Webster's Third New International Dictionary**, and authors are responsible for consistency in spelling.

Abbreviations, nomenclature, and symbols for units of measurements should follow international recommendations. Metric units, SI units and decimals should be used whenever possible. Use day/month/year sequence for dates. Do not use periods after such abbreviations as "mm, kg, DOE, NRC, etc."

Taxonomic keys should be in aligned-couplet form in zoology and paleontology, and in multi-level indent form in botany. Synonymy in botany, zoology, and paleontology should be in the short form - taxon, author, year: page - with full citation in the references.

An abstract of not more than 200 words should precede the body of the text. This should be followed by an introduction, methods, results or observations, discussion, and references. In some cases a combination of these sections may be more effective.

References should be checked with the original article and referred to in the text by author and date, in parentheses. References should be listed alphabetically at the end of the manuscript. Reference to papers in periodicals must include author, date, title, journal, volume number, and inclusive pagination. Serials are abbreviated in the form given in **Bibliographic Guide for Editors and Authors** (the American Chemical Society, 1974). For serials not found therein, the abbreviated name in the **World List of Scientific Periodicals** (Butterworths, 1963) is used. The following are examples of style for references from journals, books, and symposium volumes:

Author, A.N. and Other, T.H.E. 1978. Title of the article. *Name of Journal*, (Volume) 99: 1-10.
(Omit word volume)

Author, A.N. and Coauthor, A. 1978. *Full Title of Book*. Publisher, City.

Author, A. 1978. Title of Article. In *Title of Book or Symposium Volume*. (ed. J. Smith and B. Jones). Publisher, City, pp. 256-301.

Tables should be numbered with roman numerals, having a brief title, and referred to in the text. Vertical rules should not be used. Tables must be typed separately from the text on individual pages.

Originals of illustrations should not be more than three times the size of the final reproduction, 11 by 18 cm. Figures, including those in plates, are numbered consecutively in arabic numerals, and each referred to in the text. Original drawings, and one set of clean copy, are required and should be made with india ink on white paper. All lines must be sufficiently thick to reproduce well, and letters and characters sufficiently large to be legible and not less than 1 mm high when reduced. Captions for illustrations should be typed separately from the text.

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Color illustrations will be accepted at the discretion of the Editor. However, the cost of color reproduction is borne by the authors who must submit a statement accepting this responsibility.

Authors are responsible for editing the galley proof. Orders for reprints, in addition to the 15 supplied gratis, must be received when the galley proof is returned.

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1979-1980

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VOL. 29

1979

Part 3

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Editor: J. McLachlan

Associate Editor: C.J. Bird Production Editor: H.B.S. Cooke
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RECOMMANDATIONS AUX AUTEURS

La Revue *Proceedings of the Nova Scotian Institute of Science* publie les travaux de l'Institut, des articles originaux et des notes avant trait aux sciences naturelles aux Provinces atlantiques, surtout dans les domaines de la biologie et de la géologie. Les manuscrits peuvent être en anglais ou en français, et seront soumis à l'avis d'experts avant d'être acceptés.

Les textes doivent être dactylographiés à interligne double, sur des feuilles de papier blanc 21.5 cm sur 28 cm (8.5 po sur 11 po), avec marges de 4 cm (1.5 po). Ne souligner que les passages destinés à être imprimés en italique; utiliser les majuscules dans le seul cas où les lettres ou les mots en question doivent paraître en majuscules à l'impression. La mise en page et la typographie suivront le modèle du présent ouvrage. Le texte original doit être accompagné d'une copie. Chaque page doit être numérotée, la première page ne portant que le titre, le nom des auteurs, la mention de l'université ou autre établissement auquel ils sont affectés, et des notes infrapaginales éventuelles.

L'orthographe doit se conformer au **Larousse encyclopédique**. Les auteurs sont responsables de l'uniformité de l'orthographe dans leurs textes.

Les abréviations, la nomenclature et les symboles des unités de mesure doivent se conformer aux normes internationales. Les unités métriques (SI) et les décimales doivent être utilisées dans la mesure du possible. Pour les dates, adopter l'ordre jour/mois/année. Ne pas faire suivre d'un point les abréviations "mm, kg, ME, CNRC", etc.

Les tableaux taxonomiques doivent se présenter, dans des cas de la zoologie et de la paléontologie, sous forme de descriptions dichotomiques alignées verticalement, et pour la botanique sous forme multilinéaire étagée. La synonymie, en botanique, en zoologie et en paléontologie, doit être représentée succinctement: taxon, auteur, année: page, avec citation au complet aux indications bibliographiques.

Un résumé ne dépassant pas 200 mots doit précéder le corps du texte. Le texte lui-même doit comprendre les sections suivantes: introduction, méthodes, résultats ou observations, discussion, références bibliographiques. Dans certains cas, une synthèse de deux ou de plusieurs de ces sections peut être souhaitable.

Les références bibliographiques doivent être vérifiées auprès des publications d'origine, et doivent être identifiées dans le texte par les mentions auteur et date, entre parenthèses. Les références bibliographiques doivent être arrangées par ordre alphabétique en fin de texte. Les références aux articles parus dans des revues doivent comporter les éléments suivants: nom du journal, numéro du volume, pagination complète. L'abréviation des titres revues doivent se conformer au **Bibliographic Guide for Editors and Authors** (American Chemical Company, 1974). Pour les revues qui n'y figurent pas, consultera la **World List of Scientific Periodicals** (Butterworths, 1963). Nous donnons ci-dessous quelques exemples de référence aux revues, livres et recueils:

Auteur, U.N. et Autre, T.E.L. 1978. Titre de l'article. *Nom de la revue*, (volume) 99, 1-10, (Omettre le mot "volume").

Auteur, U.N. et Coauteur, S.O.N. 1978. *Titre du livre au complet*. Editeur, Ville.

Auteur, U.N. 1978. Titre de l'article. In *Titre du livre ou du Recueil*. (réd. A. Lenoir et B. Leblanc). Editeur, Ville, pp. 256 - 301.

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B.E. MACKEY and A.R. TAYLOR

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This Bibliography does not repeat the 1972 citations found in an earlier bibliography (Campbell, 1973).

Atlantic Regional Laboratory, Genu Products Canada Limited, and Marine Colloids Limited supplied assistance for publication costs. J. McLachlan provided advice on choice of content.

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The references included herein supplement the recent extensive bibliography, **Moyse, C.M.** 1978. Bay of Fundy environmental and tidal power bibliography. *Fish. Mar. Ser. Tech. Rep.* No. 822. The present citations were either omitted from the bibliography or published subsequently. References to BSc honours theses, internal reports, and other documents difficult to obtain are not included in this supplement.

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PHYSICAL OCEANOGRAPHIC AND SEDIMENTOLOGICAL STUDIES IN THE SOUTHERN BIGHT OF MINAS BASIN

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Physical features of water in the southern bight of Minas Basin, including salinity, temperature, light penetration, and suspended sediment concentration and size distribution, were studied during the summer of 1978. Salinities decreased from 29 ‰ at the entrance of the southern bight to < 25 ‰ at the mouth of the Cornwallis River, whereas surface suspended sediments increased from $< 10\text{mg/l}$ to $> 100\text{ mg/l}$. Time-depth studies over 12 to 13 h periods were done at 3 locations in which changes in light penetration, salinity, and sediment load at meter depth intervals were recorded. Particle size frequency distributions varied according to locality and stage of tide. Some evidence of gravity settling was noted at high tide. A survey of the lower part of the Cornwallis River was also done, including an investigation of behavior of suspended sediments in the mouth over a tidal cycle. Maximum suspended sediment load in the river was 4.9 g/l at 1/ km above the mouth—the farthest point of study.

Introduction

Minas Basin is an extensive, macrotidal estuary that, until recently, has been little studied. With renewed interest in tidal power development, a large scale program of study was initiated, firstly with geological studies (e.g. Amos & Joice 1977; Middleton 1977) and subsequently with faunal studies (e.g. Risk et al. 1977; Gratto 1978; Boates 1978; Pennachetti 1978). As part of this program a group was established to investigate the composition, abundance, and role in trophic pathways of the zooplankton.

It has been long recognised that zooplankton diversity is low in highly turbid localities. Jermolajev (1958) concluded from a study of zooplankton samples taken in Minas Basin and Channel that typical copepods from the Bay of Fundy fail to maintain themselves and starve when carried accidentally into Minas Basin. She did note, however, that some smaller species were extremely abundant in certain locations. With little phytoplankton to feed on, we assumed that these successful species must derive much of their trophic support from organic matter associated with suspended sediments. It was clearly necessary, therefore, to investigate in some detail the relationship between zooplankton and suspended sediments in a small portion of Minas Basin.

The present study was initiated to provide a clearer understanding of physical conditions in the southern bight region. The much more extensive study of Amos and Joice (1977) was necessarily conducted on a scale that provides insufficient information about small subunits of Minas Basin, particularly in shallow regions that are greatly influenced by river input. Furthermore, biological communities in the southern bight are quite different from those described by Risk et al. (1977) and Yeo (1978) for Cobequid Bay. They exhibit much greater diversity and regional heterogeneity than in the more easterly portions of the Basin. It is clearly desirable to discover reasons for these differences.

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This paper describes the first attempts made to quantify and categorise the suspended material in the southern bight region, to investigate the fate of these sediments as tidal waters moved in and out of the region, and to determine the degree to which light penetration is restricted. Water samples were taken at the same time that plankton was sampled so that possible correlations between the 2 might be detected. The objective of this study, therefore, was to establish in outline the postulated sediment-zooplankton interaction. Associated with this objective, the role of zooplankton in maintenance of local nekton populations is also under study, so that eventually an assessment of the significance of zooplankton in these highly turbid localities may be made. Preliminary results of zooplankton and fish studies are recorded in Pennachetti (1978), and more detailed accounts will be published elsewhere.

Methods

Water samples were collected at 1 m depth intervals using either a 2.1 l PVC Kemmerer bottle or a 1 l Knudsen bottle. Immediately upon retrieval of the sampler to the side of the boat, a 1 l sample was drawn off into a Nalgene bottle for analysis of suspended sediment. Surface water samples were obtained by direct filling of a sample bottle. These procedures minimized the effects of gravity settling of suspended material.

Analyses of suspended sediments were commenced within 48 h of collection for samples obtained during time-depth tidal studies, and within 4 h for survey studies. Subsamples of known volume were filtered through pre-weighed 0.4 μm Millipore or Nuclepore filters following agitation of the sample bottle to resuspend settled material. The filters were dried in a vacuum oven at $50 \pm 1^\circ\text{C}$ for 24 h and re-weighed to provide estimates of total suspended solids (S.S.C.). Size-frequency distributions were examined using a Coulter Counter Model TA II equipped with a 280 μm aperture tube. Calibration was done using 10.01 μm polystyrene microspheres, and the electrolyte employed was Millipore-filtered sea water obtained at the site and time of collection of samples. Dilutions of samples varied according to concentration.

Temperature and salinity were recorded at the site of collection using a Y.S.I. S-C-T meter. During time-depth tidal studies, light penetration was measured at 0.5 m intervals using a Kahlsico Submarine Photometer, but during some survey studies a 20 cm Secchi Disc was employed.

Results

Survey Studies

In order to provide an account of regional and temporal variations in salinity, turbidity, temperature, and suspended sediment concentrations within the southern bight, 20 sample sites were visited at high tides between 17 May and 28 August 1978 (Fig 1). A summary of the results obtained is provided in Table I; more complete details are given in Pennachetti (1978).

Sites A-C lay either in the mouth of the Cornwallis River or in the outlet channel, and for these sites the influence of the river was predominate. Salinities were on the low side (23-27‰), whereas turbidity was high because of the relatively heavy load of suspended sediments ($> 25 \text{ mg/l}$). Similar conditions were encountered in the mouth of the Canard River (site I) and that of Habitant Creek (L). At stations more distant from the river mouths (E-H, J, K, M) the influence of riverine water decreased and that of tidal water increased. This is most notable with regard to suspended

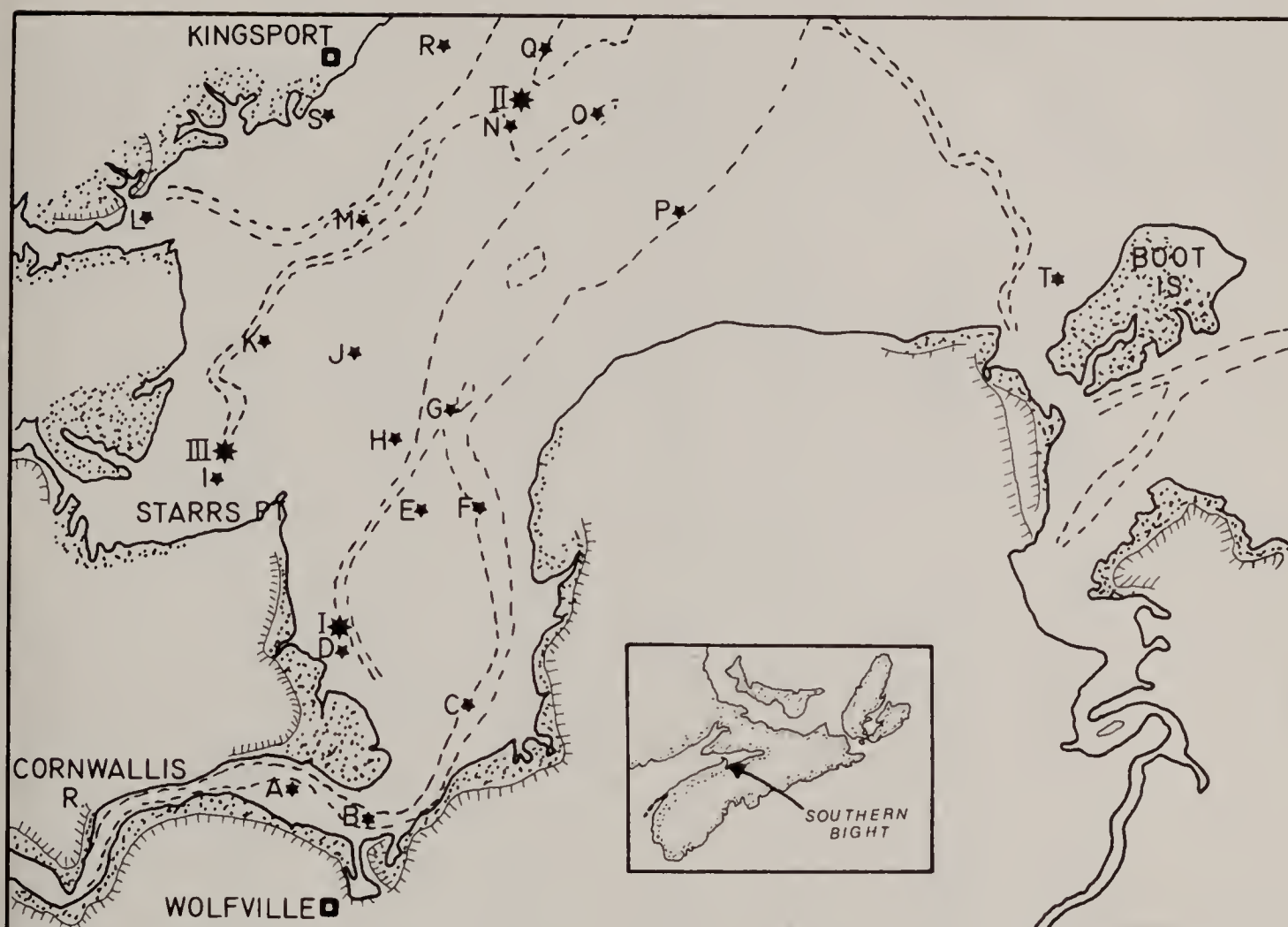


Fig 1. Southern bight of Minas Basin. A-T (small stars) Survey stations; I-III (large stars) Time-Depth anchor stations. Inset: Maritime Provinces showing study area.

sediment concentrations which were usually $< 20 \text{ mg/l}$ and in Secchi Disc depths which approached 1 m. The unusually high suspended sediment value of 41.9 mg/l obtained at site F probably indicates that a plume of undispersed river water had been sampled. The remaining sample sites illustrate the much greater clarity, higher salinity, and lower suspended sediment concentrations of true tidal water.

Because of time limitations, only a few sites could be visited on any single day. Six sites (A, D, E, I, L, and Q), however, were visited at regular intervals during the summer, and these results give some measure of temporal variability in these physical features. Considerable variation is evident, particularly in the amount of suspended material. On 1 occasion at each of sites B, D, I, and Q, water samples were taken at the surface, at mid-depth, and just above the bottom and the amount of suspended sediment present determined. In only 1 case (I) was there an indication that the water column was well mixed vertically, whereas at sites D and Q the deepest water carried a much greater suspended load than that at the surface. In the river channel (B), however, the greatest load was in the mid-depth sample, which is presumably correlated with a greater rate of flow.

Size frequency analysis of suspended sediments in surface water samples from different sites indicated a marked change in principal particle sizes as the mouth of the Cornwallis River was approached (Fig 2). At deeper locations primarily influenced by tidal water (e.g. R, O, J - Fig 2A) suspended sediments included particles at all sizes that could be measured with the $280 \mu\text{m}$ aperture used ($< 112 \mu\text{m}$ diam), with only a slight preponderance of particles 6 to $20 \mu\text{m}$ diameter. In contrast, samples from shallower stations (D, E, H, L - Fig 2B) and the river (B, F - Fig 2C) ex-

Table I. Physical features of the southern bight of Minas Basin, 1978.

Station	Date (day/mo)	H.T.* Time	Sample** Time (h)	Max. Water Depth (m)	Temp. (°C)	Sal. (° / ‰)	S.S.C.*** (mg/l)	Secchi Disc Depth (m)
A	19/5	1039	-0.9	7.0	11.1	23.5	-	0.3
	24/5	1444	-1.6	9.8	10.1	25.8	-	-
	9/6	1609	-1.2	-	15.5	23.2	109.6	-
	3/8	1324	-1.4	-	20.0	25.0	-	-
B	9/6	1609	-0.9	8.5	13.5	24.8	32.4(s) 78.0(m) 25.7(b)	-
C	3/8	1324	-1.1	9.0	20.0	27.0	-	-
D	19/5	1039	-0.4	7.5	9.0	29.0	-	0.6
	24/5	1444	-1.2	7.0	9.9	26.5	-	-
	9/6	1609	-0.8	9.5	12.3	26.8	14.9(s) 15.3(m) 121.2(b)	-
	7/7	1504	-1.7	-	-	-	30.5	0.6
	21/7	1409	-0.2	10.0	16.5	-	13.1	-
	3/8	1324	-0.8	9.5	21.0	26.2	-	-
E	19/5	1039	-0.2	4.5	9.5	25.5	-	0.5
	24/5	1444	-0.9	7.3	9.3	26.3	-	-
	9/6	1609	-0.2	-	13.0	25.0	4.9	-
	21/7	1409	-0.6	5.9	16.0	-	17.7	-
	3/8	1324	-0.7	9.0	18.0	28.0	-	-
F	7/7	1504	-1.3	-	-	-	41.9	0.6
	21/7	1409	-0.8	>17.0	16.5	-	15.4	-
G	3/8	1324	-0.5	12.5	20.5	26.8	-	-
H	19/5	1039	+0.3	8.0	8.6	25.5	-	1.0
	24/5	1444	-0.7	13.3	8.6	26.5	-	-
	7/7	1504	-2.1	-	-	-	22.1	0.7
	21/7	1409	-1.1	5.9	16.0	-	10.8	-
I	24/5	1444	+0.3	11.0	10.0	26.1	-	0.9
	9/6	1609	-0.7	6.7	-	-	3.5	-
	23/6	1514	-1.1	6.2	16.5	23.1	83.0	0.7
	7/7	1504	-1.6	-	-	-	17.6	-
	21/7	1409	-0.5	5.5	19.5	26.5	27.1(s) 22.2(m) 24.7(b)	0.6
	3/8	1324	-0.8	5.5	18.6	-	-	0.9
J	23/6	1514	-1.6	7.0	15.0	23.8	-	1.0
	21/7	1409	-0.7	5.5	18.0	26.7	16.1	-

Station	Date (day/mo)	H.T.* Time	Sample** Time (h)	Max. Water Depth (m)	Temp. (°C)	Sal. (° / ‰)	S.S.C.*** (mg/l)	Secchi Disc Depth (m)
K	17/5	0859	-1.8	4.5	10.0	26.1	-	0.8
	7/7	1504	0	-	-	-	12.4	-
L	17/5	0859	-0.2	6.5	11.0	26.0	-	1.2
	24/5	1444	+0.6	8.8	9.5	26.3	-	0.6
	23/6	1514	-0.6	5.2	18.0	24.1	124.9	0.9
	7/7	1504	-1.9	-	-	-	15.2	-
	21/7	1409	-0.3	14.4	17.0	-	11.0	-
	3/8	1324	-0.6	9.0	18.9	-	-	1.2
M	17/5	0859	0	-	9.5	26.0	-	1.2
	3/8	1324	-0.3	7.3	17.1	-	-	1.5
N	7/7	1504	-0.8	-	-	-	7.5	-
O	17/5	0859	-	-	8.2	26.5	-	-
	21/7	1409	-0.8	14.0	17.0	26.0	9.2	1.5
P	23/6	1515	0	14.0	12.0	26.0	8.5	1.6
Q	24/5	1444	-1.2	11.0	8.0	26.5	-	1.3
	9/6	1609	+0.4	14.6	-	-	3.5	-
	23/6	1414	-0.3	15.0	12.2	21.1	21.4	1.6
	7/7	1504	-1.1	-	-	-	8.5	-
	21/7	1409	-1.3	12.0	18.2	24.9	11.1(s) 11.9(m)	1.5
	3/8	1324	-1.2	11.5	17.0	-	16.9(b)	-
R	9/6	1609	+0.6	-	-	-	1.8	-
	3/7	1324	-0.2	>6	17.1	-	-	1.5
S	9/6	1609	-1.2	8.3	-	-	2.5	-
T	24/5	1444	-0.7	7.0	9.5	26.3	-	0.8

* H.T. - time of high tide predicted for Walton (Canadian Tide and Current Tables 1978)

** Sample time in hours relative to predicted high tide time (e.g. -0.5 indicates samples taken 0.5h before predicted high tide).

*** S.S.C. = Suspended sediment concentration. s = surface sample; m = mid-depth sample; b = sample taken near max. depth, but above bottom. Except where indicated otherwise, all samples were taken at the surface.

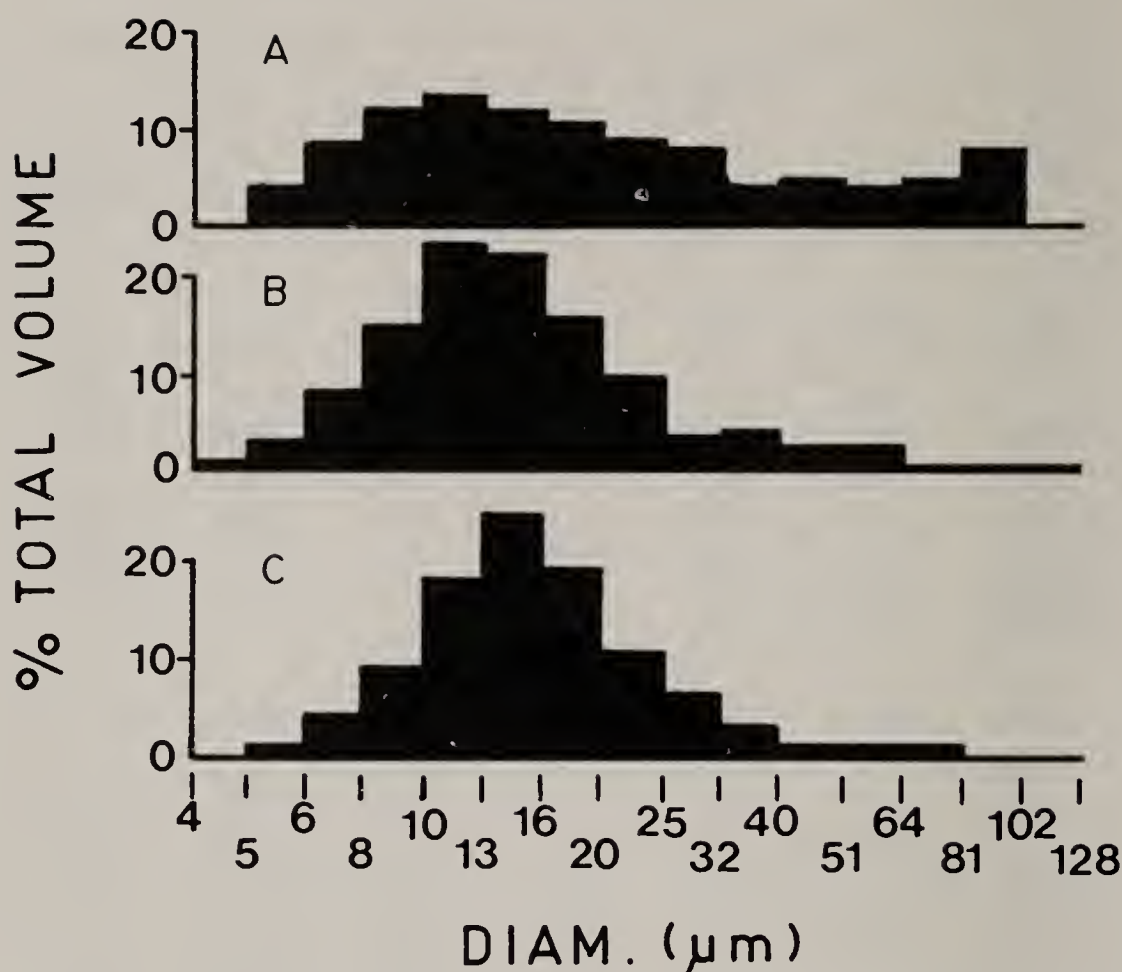


Fig 2. Typical particle size-frequency distributions in the surface waters at high tide. A - pattern at deeper water stations; B - inshore stations over mudflats; C - River mouth station.

hibited a distinct peak in the 10 to 20 μm range and a low percentage of particles $> 40 \mu\text{m}$ diameter. We attribute this change in percentage frequency to a combination of 2 factors: the resuspension of fine particles from the surface of the mud and the partial settling out of larger particles and flocules (Krank 1978) as velocities decreased when the water moved over the mud flat.

Time-depth Tidal Studies

Although some general trends in salinity and suspended sediment concentrations are evident from the survey sample results, it was obvious that physical conditions at any given point varied markedly according to the stage of the tide. Tide-related changes were expected to be even greater in shallower waters such as the southern bight than were recorded by Amos and Joice (1977) from their metered stations near Blomidon. For this reason 3 studies were carried out in which hourly samples at 1 m depth intervals were taken from a single point over 12 to 13 h periods. Because of the difficulties of access and the small ($< 14'$) boats employed, the time-depth tidal studies commenced at a convenient morning high tide and continued until the next high tide. Locations of the time-depth studies are indicated in Figure 1.

i) Wolfville Station (1) 29 May: On the first time-depth study, sampling began at 0830 h, just after high tide, and continued until 2000 h. Between 1200 and 1500 h the boats used were left stranded on the mud flat as the water receded further than expected. Results of this series are presented in Figure 3.

Vertical temperature and salinity data indicate clearly that in general the water column is moderately to well mixed, temperatures rarely varying by $> 1.5^\circ\text{C}$ from top to bottom of the water column. The diel temperature fluctuation would appear

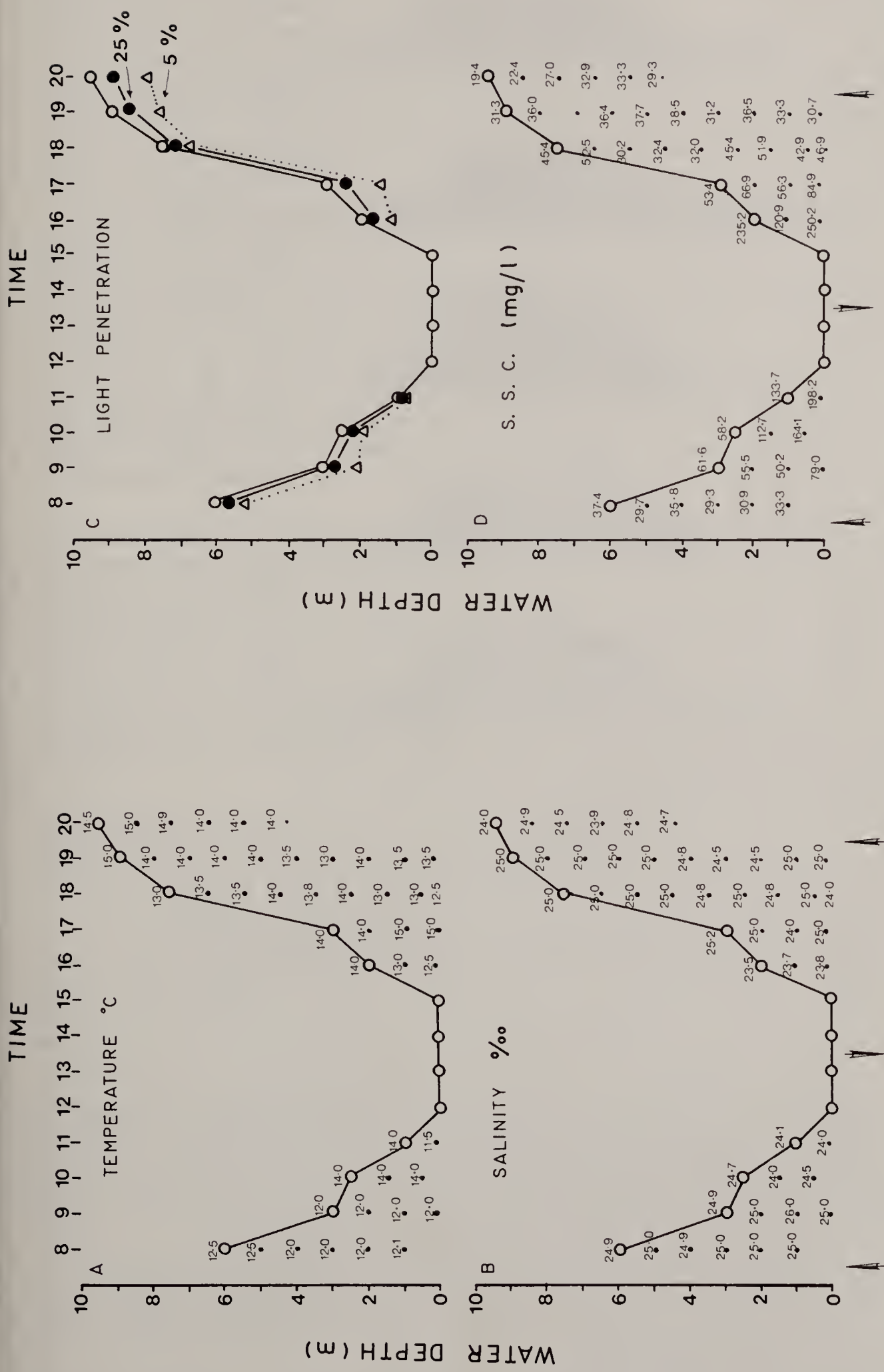


Fig 3. Time-depth patterns of Temperature (A), Salinity (B), Light penetration (C), and Suspended Sediment Concentration (D) at site 1, 29 May 1978. o—o water depth; • sample points; high tides; ↓ low tides.

to have been of greater importance than the tidal; during the morning hours while the tide was ebbing, temperatures were somewhat cooler than on the afternoon flood tide. Exposed mud flats such as these accumulate a great deal of heat when low tide occurs at midday, and this heat is transferred to returning flood water. Similarly, vertical salinity variations were also small, being not much greater than might be attributed to instrument error. Light penetration was greatly restricted as a result of the high suspended sediment load. Maximum depth at which 5% of incident surface light occurred was about 1 m at the time of high tide corresponding to a Secchi Disc reading of 0.5 m. During both ebb and flood, however, the much greater quantities of suspended sediments resulted in shallower light penetration.

Greatest vertical inhomogeneity in the water column is seen in the suspended sediments. Mean concentration in the water column rose from about 33 mg/l at 0800 h to 165 mg/l by 1100 h as the tide ebbed, whereas on the flooding tide mean concentration decreased from 202 mg/l to 27 mg/l at the next high tide. Within each column sampled, variations in concentration suggest that vertical mixing was incomplete, but it must be noted that only a single sampler was in use, so that the samples collected at any given hour were not simultaneous. The decline in concentration near high tide is largely attributable to dilution by the somewhat clearer water coming from the open part of the Basin, but might also be the result of gravity settling of larger suspended particles as current speeds diminish.

An examination of particle size frequencies in each sample taken failed to verify the occurrence of gravity settling, probably because of the incomplete data set available at 2000 h. Figure 4 presents selected size frequency distributions obtained during this study. As with previous samples (Fig 2) a wide spectrum of sizes was present in most samples, with a broad peak over the 10 to 40 μm range. In some samples from deeper water, however, the size distribution curve is even flatter because of the presence of a few large particles $< 100 \mu\text{m}$ diameter (e.g. Fig 4B). Near high tide at 2000 h a marked increase in modal size occurred with depth: from 10 to 16 μm at the surface (C) to 20 to 32 μm at depths of 4 and 6 m (D, E).

ii) *Longspell Point Station, 16 and 29 June.* A second series of time-depth samples was commenced on 16 June at a point farther out in the Basin. Because of equipment limitations, only light penetration and partial temperature profiles were obtained on this date, and accordingly the site was revisited on 29 June to obtain a series of suspended sediment samples. Results from these two dates are given in Figure 5.

Temperatures on 16 June ranged from 13°C at the morning high tide to 21°C at low tide when water depth was < 5 m (Pennachetti 1978). The water column was essentially homothermal at all times with a maximum range of 1.5°C over a depth of 15 m. Light penetration was considerably greater than at the Wolfville site with the 5% light level being at a depth of 5 m during the morning high tide. As the tide ebbed, however, suspended sediment concentrations increased considerably (e.g. from ca. 8 mg/l at high tide to > 20 mg/l at low tide on 29 June) and correspondingly, the depth of 5% light penetration decreased to about 2 m. During the afternoon flood tide, sediment concentrations decreased once more, and on the flood tide of 16 June some increase in light penetration was noted (Fig 5). Since these data were obtained on separate occasions no further consideration is warranted.

Particle sizes in samples taken on 29 June were generally more symmetrical in distribution than those obtained over the mud flat near Wolfville. Modal size in most cases was in the 10 to 16 μm range. There was a little evidence of gravity settling at slack water (cf. Pennachetti 1978).

iii) *Canard River Station, 13 July.* The sample site in the mouth of the Canard River was in the middle of the main drainage channel and thus the boats remained with a small amount of channel water at low tide. As a consequence of the location, the

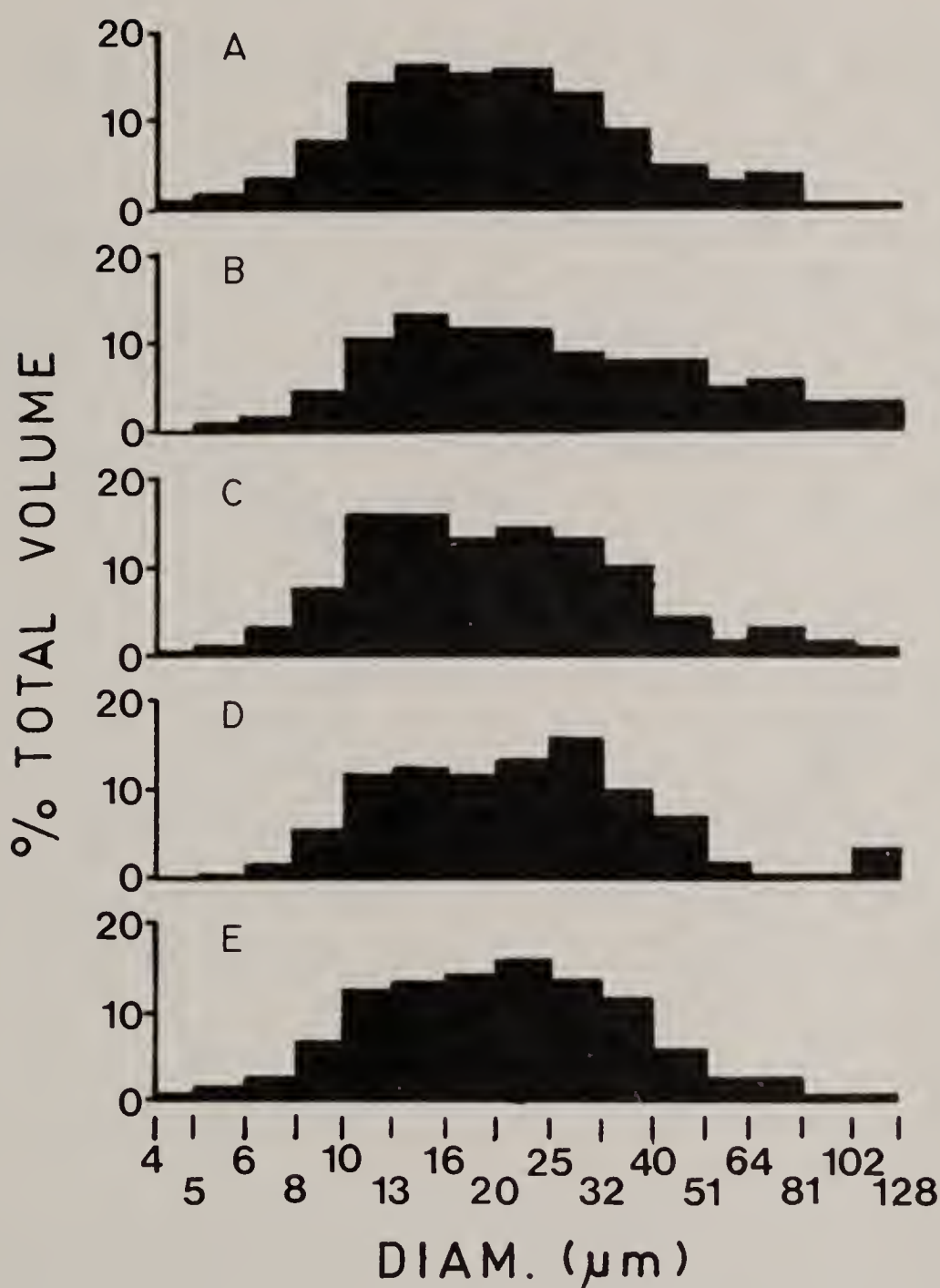


Fig 4. Particle size-frequency distributions of selected samples from 29 May 1978 time-depth study.

A - Surface sample, 1000 h; B - Bottom sample 1600 h;
C - Surface sample, 2000 h; D - 4m sample, 2000 h; E - 6 m sample, 2000 h.

pattern of the ebb and flood tide was unusual, with an anomalous increase in depth mid-way through the ebb tide and a similar decrease in depth half way through the flood (Fig 6). These events are presumably caused by frictional resistance to sheet flow over the surrounding flats which in the first instance impedes drainage into the channel, and in the second, away from the channel over the mudflats.

Temperature results reflect those obtained on earlier time-depth studies. At most sample times there was little difference in temperature from top to bottom of the water column, but near the evening high tide (1930 h) an inversion of the usual pattern occurred when cooler, more saline water appeared to be overriding warmer, less saline water. It is probable that this unstable configuration resulted from the constraining effect of the steep channel walls preventing much lighter water from riding out over the incoming tidal water.

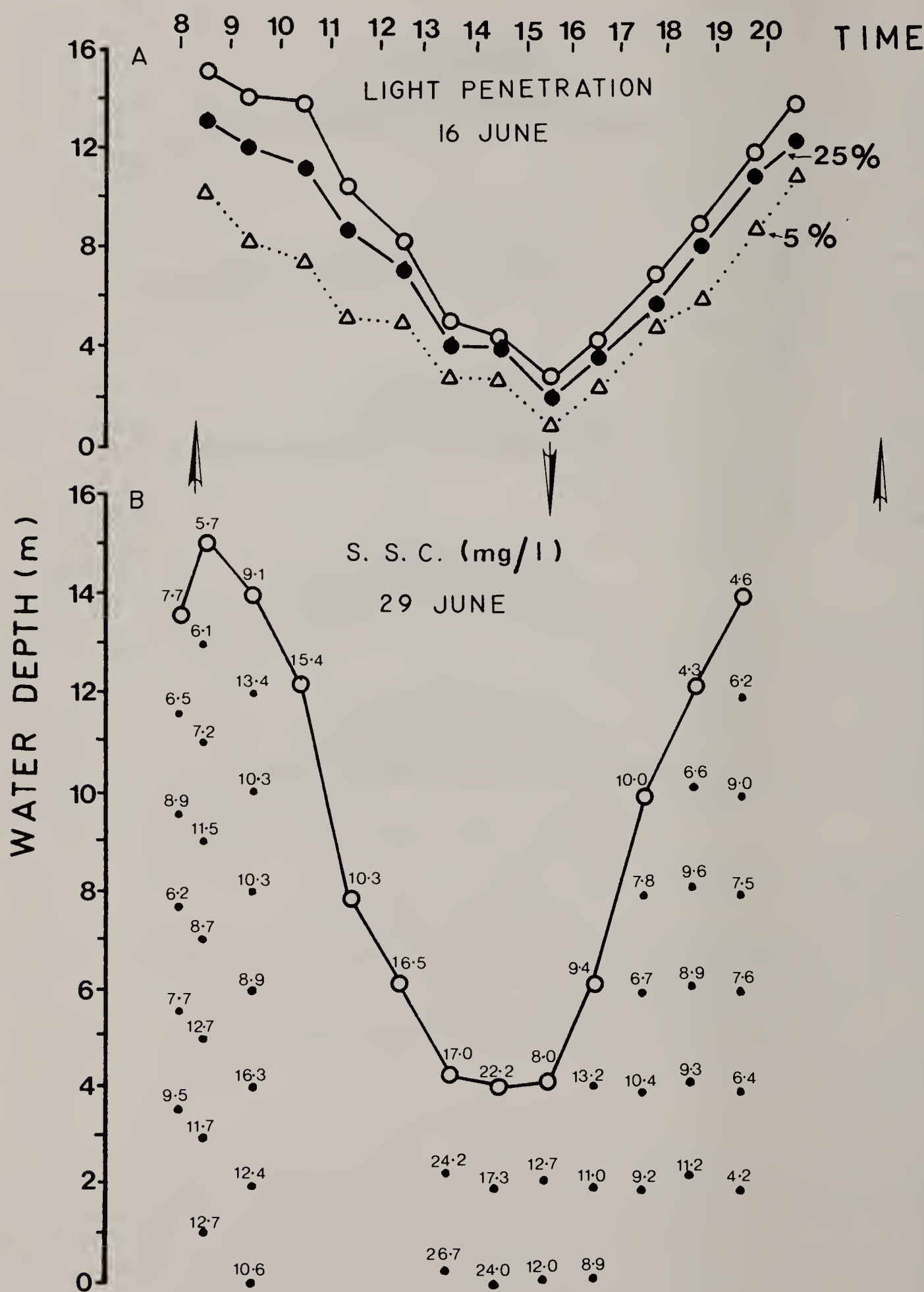


Fig 5. Light penetration (A), 16 June 1978 and Suspended Sediment Concentration (B), 29 June 1978 during time-depth studies at site II. Symbols and units as Fig 3. Note differences in vertical scale.

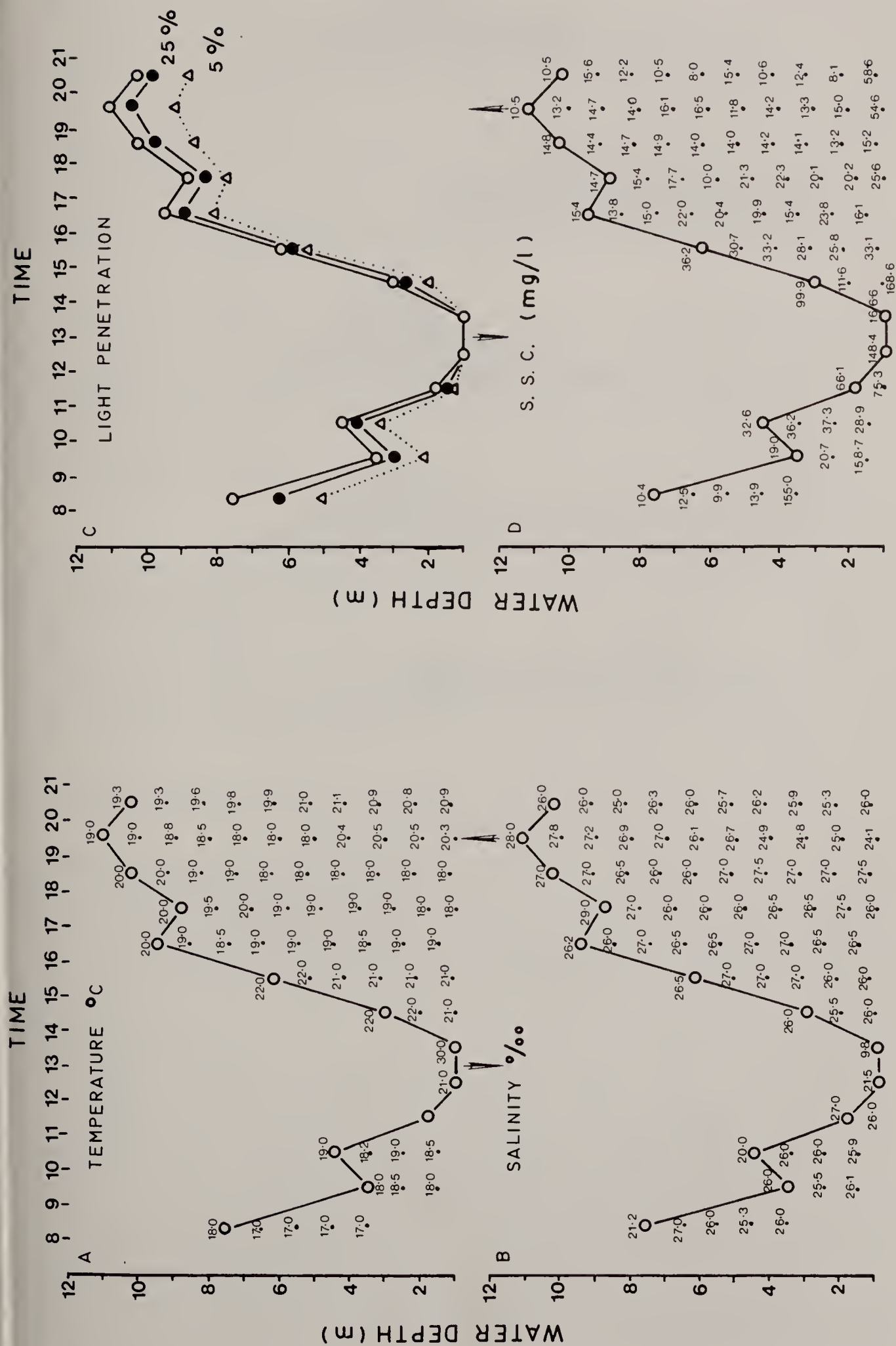


Fig. 6. Time-depth patterns of Temperature (A), Salinity (B), Light Penetration (C) and Suspended Sediment Concentration (D) at site III, 13 July 1978.

Salinities ranged from as little as 9.8 ‰ at low tide when the channel contained mostly Canard River water to a maximum of 29.0 ‰ during the flooding tide. Except for the high tide condition noted above, there was little vertical inhomogeneity. Maximum light penetration occurred near the high tides, the 5% level being at 1.5 to 2.5 m, and minimum penetration at low tide when 95% of surface light was extinguished at 0.3 m depth. Correspondingly, suspended sediment concentrations were high ($> 140 \text{ mg/l}$) around low tide and diminished sharply ($< 17 \text{ mg/l}$) towards the high tide. It is notable that several bottom samples exhibited much greater quantities of sediment in suspension than water immediately above (e.g. 0830, 0930, 1430 etc.). This phenomenon is also undoubtedly related to channel shape, and presumably indicates an extremely turbid layer near the bottom that does not get completely mixed with the rest of the column because of the restraining channel walls.

Particle size distributions were much more variable in these samples than in previous studies. Although most samples exhibited a skewed broad spectrum with modal sizes in the 10 to 16 μm range (Fig 7A), some bottom samples showed spectra that were highly truncated at the low end (Fig 7B) as a result of the dominance of particles $> 20 \mu\text{m}$. On the evening high tide a progressive shift in mode from a 10 to 13 μm at the surface (Fig 7C) to $> 20 \mu\text{m}$ (D, E) suggests a significant gravity settling effect. Because of the entraining effects of the channel at this site, however, interpretation of these results must be cautious.

Cornwallis River Study

A major source of freshwater for the southern bight region is the Cornwallis River. In order to examine the fate of particulate material carried in suspension by water in the river a series of surveys was carried out to provide a descriptive account of suspended sediments and salinity along the course of the river. One such survey is reported here; the remainder are described in Pennachetti (1978). Subsequent to these surveys, a study was conducted of the changes occurring over one tidal cycle at 2 locations in the river.

i) 21 June survey. A survey of surface waters from the mouth to $> 11 \text{ km}$ above the mouth of the Cornwallis River was carried out near high tide on 21 June. Results are given in Table II, and location of sample stations in Figure 8.

Salinities decreased from 25 ‰ at the mouth of the river to 20 ‰ at the uppermost station sampled. Although not evident in this particular survey because of wind activity, the mouth of the Cornwallis River occasionally exhibits lateral stratification with higher salinities along the southern shore where flood water more strongly and lower salinities along the northern shore where river outflow is more important. This effect is limited to the lower reaches of the river and has not been noted above station 9.

Suspended sediment concentrations increased greatly from about 50 mg/l at the mouth to $> 4500 \text{ mg/l}$ at the upper stations. Secchi Disc visibility is $\leq 1 \text{ cm}$ for several km further upstream than examined in this survey. The size distribution of suspended particles also showed a progressive change along the course of the river. At the more upstream stations the percentage volume distribution was almost uniform over the range 8 to 100 μm (Fig 9A), but at intermediate (B) and lower stations (C) a more symmetrical pattern around a mode of 16 to 20 μm was evident. It is not certain how much influence was played by sample time in determining these frequency distributions. While all samples were obtained at the surface around high tide on the same day, sampling commenced at the upstream station (39) before high tide and proceeded downstream, the whole series taking 1.5 h. The lowest stations were sampled at slack water. If gravity settling occurred, its effect would be to remove the largest particle sizes from the surface and leave a distribution skewed to

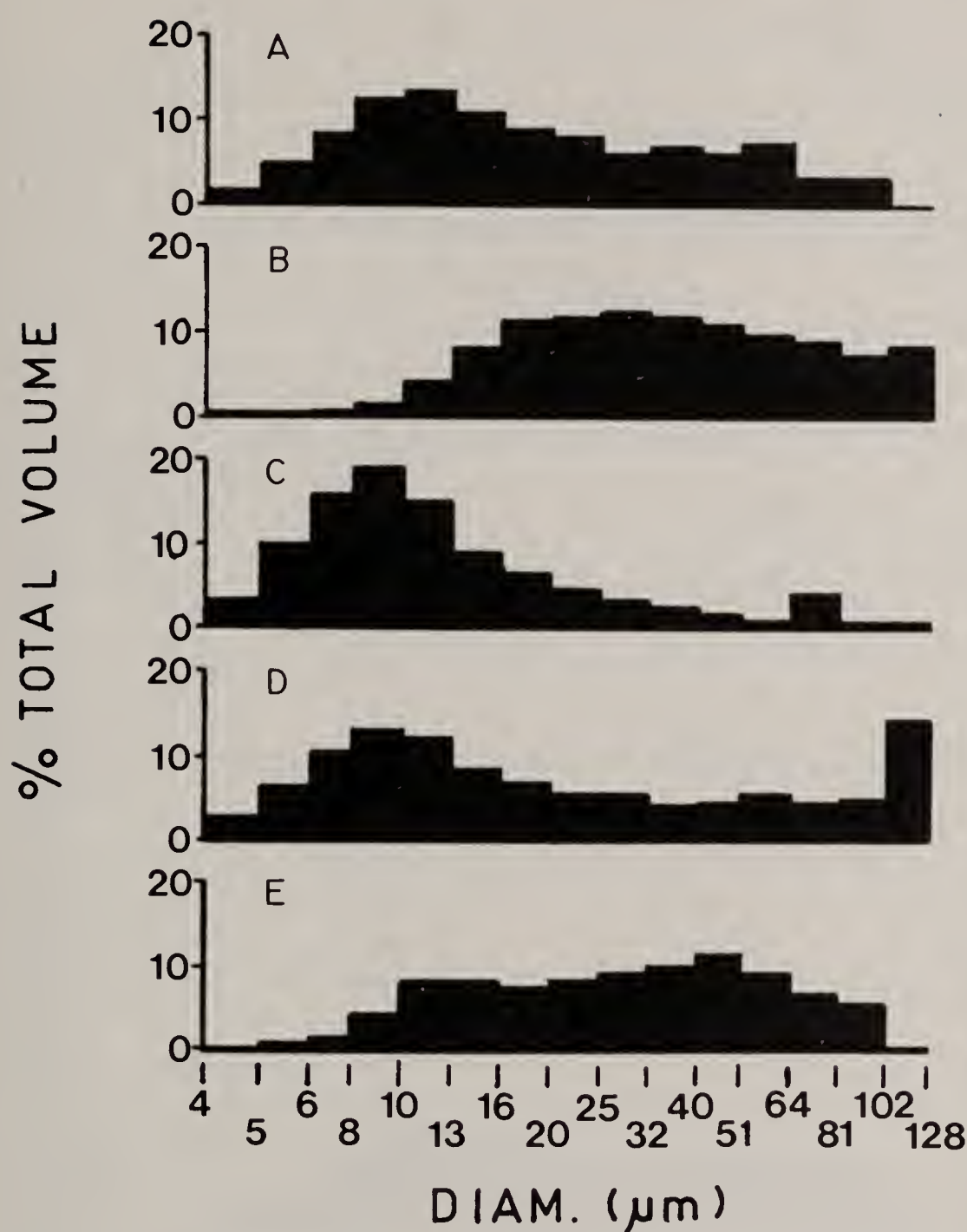


Fig 7. Particle size-frequency distributions of selected samples from 13 July 1978 time-depth study.

A - 5 m depth, 1830 h; B - 2 m depth, 0930 h; C - Surface sample 2030 h; D - 4 m depth, 2030 h; E - Bottom (9 m) sample, 2030 h.

the lower end of the spectrum. The effect would be greater at the lower stations. The symmetry observed at the lower stations, however, suggests this effect is negligible.

ii) *Tidal study, 6 July.* In order to investigate temporal phenomena related to tidal movements in the mouth of the river surface, water samples were taken in midstream at two points (Stations 2 and 13, Fig 8), one near Wolfville at the mouth of the river, and the other at Port Williams bridge. Results are given in Figure 10.

Extensive changes in salinity were recorded at both stations, reaching maximum values of 23.5 ‰ at the Wolfville station (2). During the ebb tide, however, salinity decreased more rapidly at the outermost station than at Port Williams, and for the last 3 hours the upstream station was, paradoxically, more saline than the lower station. Whether this is related to temporal stratification at the mouth is unknown.

Temperatures at both stations varied irregularly during the tidal cycle over a range of 1.5°C. A diurnal heating effect is presumably indicated by the fact that

TABLE II. Physical features of the Cornwallis River, 21 June 1978.

Station	Temperature (°C)	Salinity (° / ‰)	S.S.C. (mg/l)
1	13.0	25.1	69
2		25.1	52
3		25.2	55
4		25.2	67
5		25.1	49
6		25.0	89
7		25.0	106
8		25.1	66
9		24.2	109
10		25.0	90
11	13.0	25.4	102
12		25.1	229
13		25.0	442
14		25.1	2248
15		24.7	160
16		25.0	306
17		24.0	1195
18		24.1	2210
19		25.0	186
20		24.9	282
21	13.8	24.6	345
22		24.3	403
23		24.2	713
24		24.9	288
25		23.8	154
26		23.7	687
27		24.1	564
28		24.0	1751
29		23.5	754
30		23.2	1435
31	13.8	23.3	924
32		23.8	1290
33		22.2	2011
34		22.4	1123
35		21.8	2772
36		22.0	4060
37		21.0	2374
38		21.1	4923
39		20.1	4656

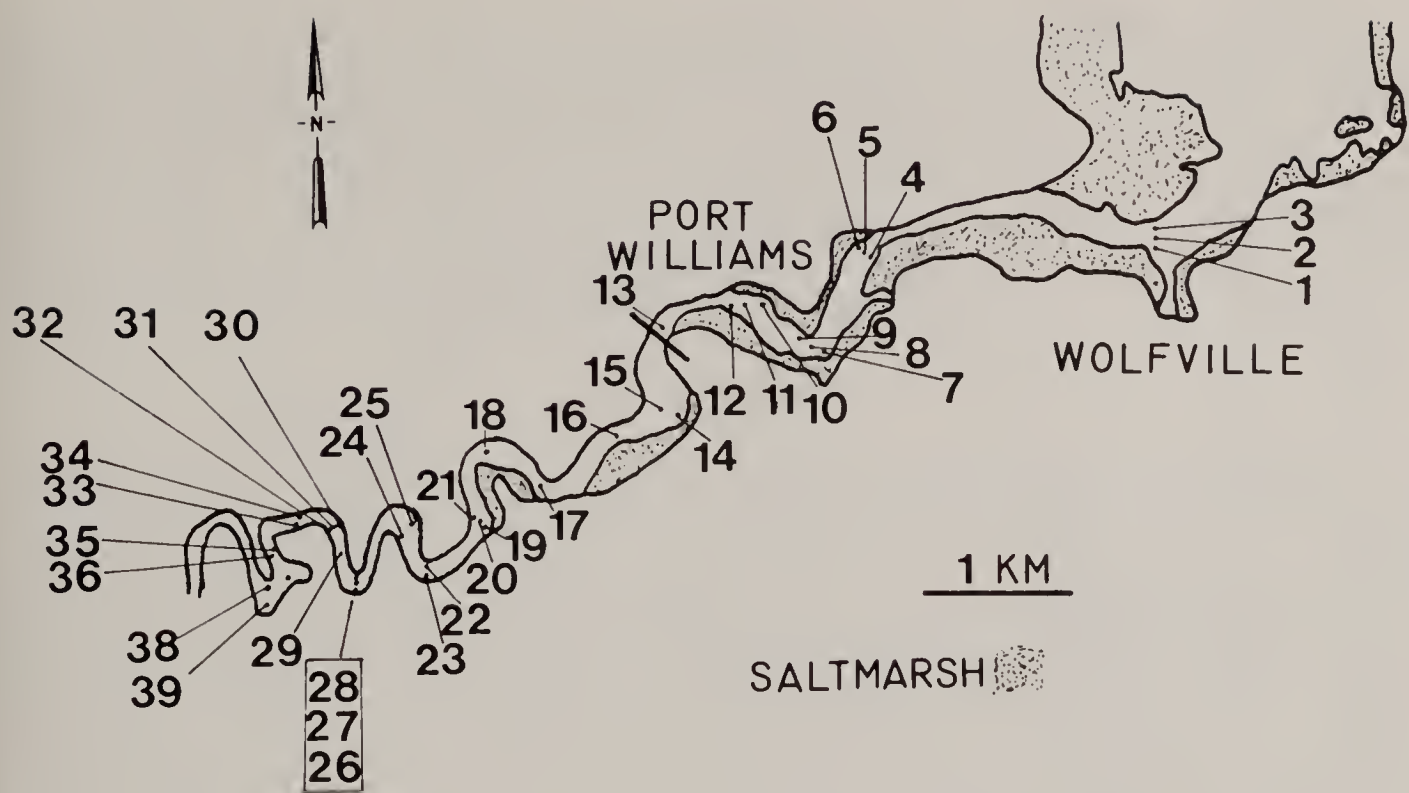


Fig 8. Cornwallis River. 1-39: sample stations, 21 June 1978.

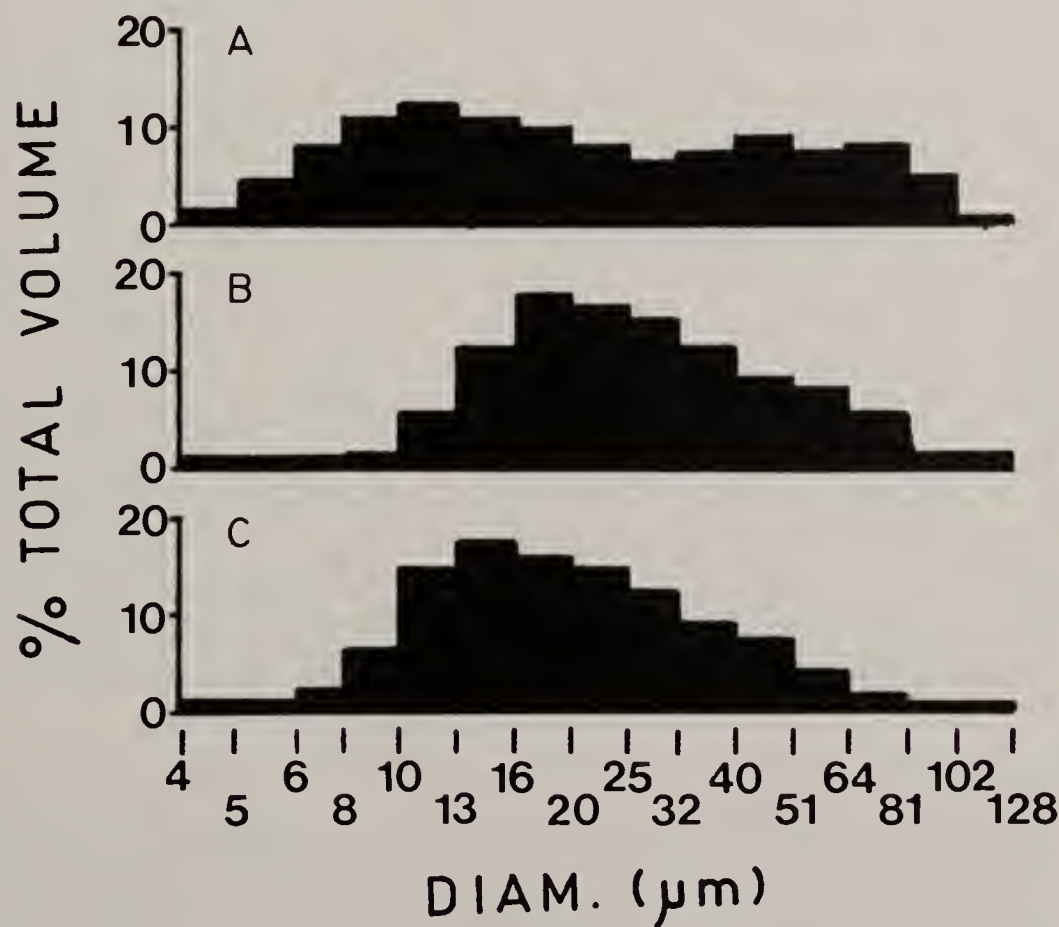


Fig 9. Particle size-frequency distributions of selected surface samples from Cornwallis River, 21 June 1978.
A: station 37; B: station 13; C: station 3.

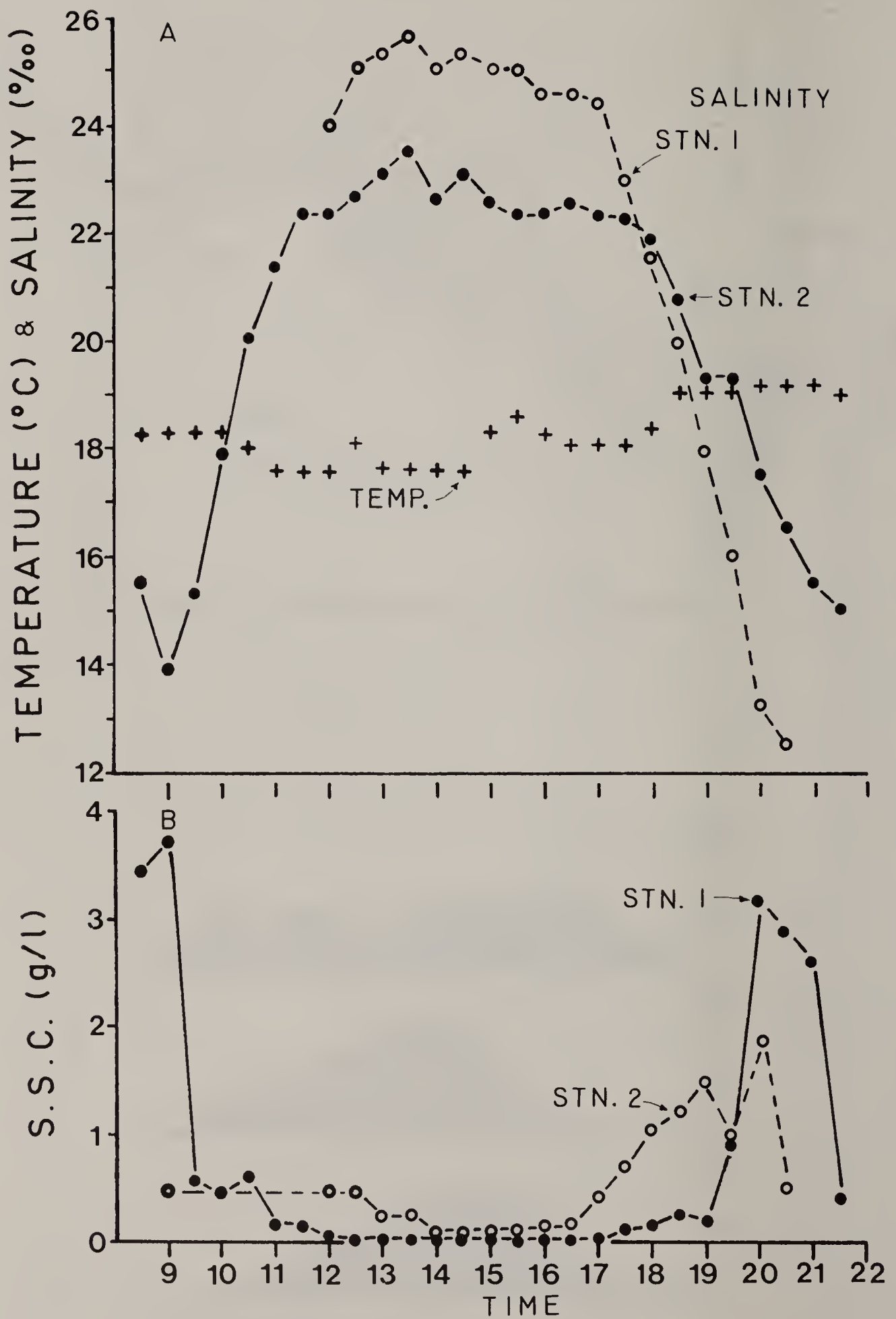


Fig 10.

Temporal changes in surface waters at 2 stations on Cornwallis River, 6 July 1978.

A - Salinity changes at Port Williams (stn. 1) and Wolfville (stn. 2) and Temperature changes for both stations.

B - Changes in Suspended Sediment Concentration at Port Williams and Wolfville. Note - units in g/l

evening low tide temperatures were about 1°C higher than at the morning low tide.

Suspended sediment concentrations were extremely high at Port Williams during low tide, and decreased sharply as the flood tide brought in Minas Basin water having much lower concentrations. Over the high tide period at these two stations the surface waters carried < 200 mg/l of suspended sediment. Coulter counter analyses of these water samples show considerable changes in size distribution, including evidence of gravity settling at high tide (Pennachetti 1978).

Discussion

In the present study the concentrations of suspended sediments measured in surface waters at high tide correspond well to the ranges interpolated by Amos and Joice (1977) from Landsat imagery. With proximity to the mouth of the Cornwallis River, sediment levels increase substantially and continue to increase over the lower 11 km of river channel. The suspended sediments that are present in the river mouth at high tide, however, are not apparently transported out into the southern bight in any quantity on the ebb tide. At all stages of the tide the water in the southern bight is considerably less turbid than that in the river mouth. Furthermore, on calm days sharp lines of demarcation are evident at high tide between the clearer water entering the southern bight from Minas Basin, and residual water that remains in the bight but oscillates back and forth over the mud flats and into the river mouth. Finally, the mud flats of the region appear to have accumulated little in recent years, suggesting that the suspended sediments are almost in dynamic balance with fluvial supply. According to Amos and Joice (1977) the only nearby sites of active erosion are at Kingsport. Since most erosion occurs at high tide, particularly when winds blow onshore, the direction of ebb flow would tend to remove eroded material away from the southern bight and thus not cause further accretion at inner regions of the bight.

Our conclusion is, therefore, that the evidence obtained indicates little loss of suspended material from the southern bight occurring as a consequence of tidal movements alone. It should be noted, however, that all our studies were conducted on calm days. Thus, we were only examining the simple effects of tidal oscillations. Yet, as Yeo and Risk (1979) have demonstrated, the major causes of erosion and translocation of deposited sediments in Minas Basin are storms or other strong wind activity. By maintaining turbulence at high tide, strong winds could certainly cause material resuspended on the flooding tide to travel well beyond its probable point of deposition on the ebbing tide. Clearly our studies provide no insight into the fate of suspended sediments under more typical Nova Scotia conditions.

In a series of time-depth studies the vertical distribution of suspended material was examined closely in order to detect the occurrence of gravity settling. Unequivocal evidence of this was not obtained, for a variety of reasons. Nonetheless, there is sufficient indication that a pattern of resuspension and deposition does occur.

Particle size frequency distributions varied considerably, primarily in relation to location in the southern bight, but also in relation to stage of tide. Broad, almost flat percentage volume distributions over the range of 10 to 128 μm were typical of off-shore locations, whereas distributions were peaked around 10 to 20 μm at high tide over mud flats. The nature of the sedimentary material was examined in a series of S.E.M. photographs of suspended sediment filtered onto 0.45 μm Nuclepore filters (Pennachetti 1978). The samples were taken during the 29 May time-depth study near Wolfville. Examination of these photographs suggests that many particles > 20 μm were flocculated, but few of these floccules were > 80 μm . There was no evidence

of nanoplankton. Samples exhibiting significant quantities of material $> 80 \mu\text{m}$ diameter occurred both onshore at a river mouth, or offshore at the entrance to the southern bight. In the latter location, diatoms (viz. species of *Rhizosolenia*, *Coscinodiscus*, and *Biddulphia*) were fairly common and were major components of the $> 80 \mu\text{m}$ classes. Diatoms were generally absent or infrequent in the river mouths, and the more regular percentage volume frequency distribution undoubtedly reflects the presence of sand grains and detritus.

These changes in particle type are probably correlated with changes in zooplankton distribution. At the entrance to the southern bight region, the summer zooplankton is a moderately heterogenous assemblage of copepods, with a few coelenterates, chaetognaths, and larval stages of benthic animals. The most abundant species is usually *Eurytemora herdmani*. In the more turbid regions closer to the river mouths, however, *Eurytemora* becomes even more dominant (see Daborn & Pennachetti 1979). This species is well known to be associated with highly turbid waters and maintains itself well on particulate material $< 60 \mu$ diameter even when this is predominantly non-living detritus (Heinle et al. 1977). Other copepods, however, may not be able to maintain themselves on non-living material, and thus would be unable to reside in inner portions of the bight.

The studies reported herein provide a valuable background to the physical conditions occurring in the water column during summer months in the southern bight. Much needs to be learned, however, before the essential features of this correlation may be described. We know very little, for example, about the organic composition of sedimentary material, and the role played by the relatively extensive salt marshes that surround the southern bight. It seems probable that organic content in the more turbid regions of the southern bight is higher than in comparable sections of Cobequid Bay, which may explain some of the apparent biological differences between the two regions. There is certainly need for much more study of the biological significance of suspended material before we can make predictions about the effects of dam construction in the region.

Acknowledgements

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BASELINE LEVELS OF TRANSITION AND HEAVY METALS IN THE BOTTOM SEDIMENTS OF THE BAY OF FUNDY

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Total concentrations of Zn, Cu, Pb, Co, Ni, Cr, V, Hg, Cd, Be, As, Ba, and Se vary regionally and with sediment texture in the Bay of Fundy. Relatively high concentrations occur in fine grained sediments from the "Quoddy region" of the Bay and near a dredge disposal site off St. John Harbour. Low concentrations of the metals occur in the sandy sediments from the central and eastern part of the Bay. Average levels of the elements are at or near natural levels when compared with levels found elsewhere in unpolluted sediments.

Introduction

The Marine Ecology Laboratory and others have begun an evaluation of the Bay of Fundy ecosystem and the potential environmental impact of tidal barrages on this system. As part of these studies, a series of environmental geochemical studies have been made to determine the levels, behavior and dynamics of potential biologically toxic metals in the sediments of the Bay. This paper reports on the abundance and distribution of Hg, Cd, Zn, Cu, Pb, Co, Ba, Ni, Cr, Be, V, As, and Se, in the Fundy sediments and compares them with levels found in comparable sediments elsewhere in the region and the world.

Field and Laboratory Methods

Sediment samples at 84 locations were obtained with a Van Veen (0.1 m²) grab. The samples were placed in plastic bags or vials and refrigerated or frozen on board ship until it returned to the laboratory. Representative portions of the samples were air-dried and stored in air-tight bottles until used for sedimentological and chemical analyses.

After removal of material > 2 mm, the sand (particles 2-0.05 mm diam) and pelite or mud (particles < 0.05 mm diam) were separated by wet sieving. These data were used to determine the partition of those components in the sediments and to classify the sediments in the Bay according to the nomenclature of Loring and Nota (1973).

Hg, Zn, Cu, Pb, Co, Ba, Ni, Cr, Be, and V were analysed by atomic absorption spectrometry using the techniques described by Loring and Rantala (1977). Using these methods, the coefficient of variation in the USGS standard mud MAG-1 was: Co 10%, Ni 7%, Cr 2%, V 3%, Zn 2%, Pb 19%, Cu 14%, Ba 6% (Rantala & Loring 1978). Arsenic was determined by Bondar-Clegg Ltd. using a colorimetric method in which 0.2 g sample was digested in a HNO₃-HClO₄ mixture for 3 h. Mercury was determined in this laboratory by the cold vapor atomic absorption method comparable to that described by Hatch and Ott (1968). Total cadmium and selenium were determined by Dr. C. Elson, St. Mary's University, Halifax, N.S., using a standard flameless atomic absorption technique.

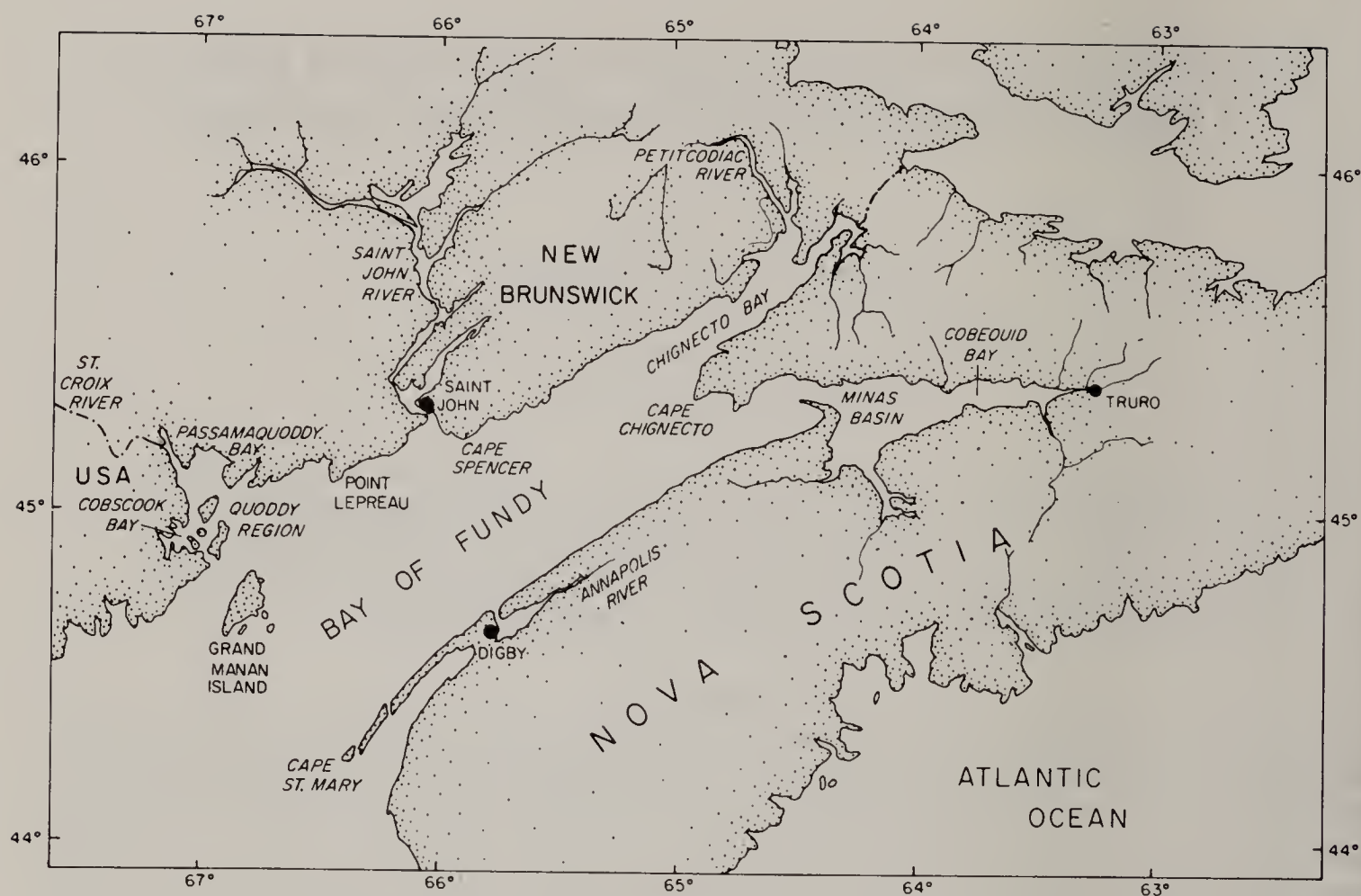


Fig 1 Place names in the Bay of Fundy

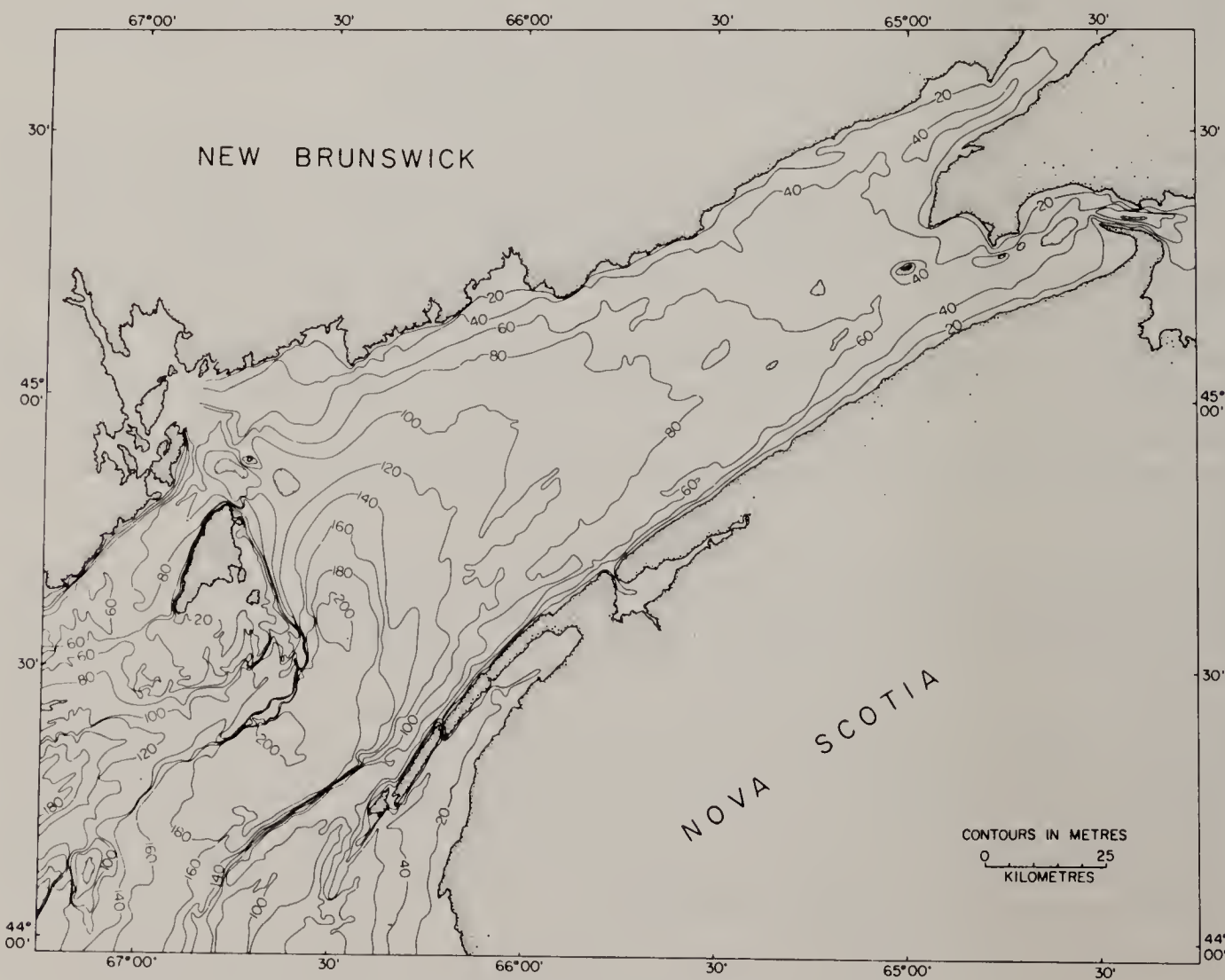


Fig 2 Bathymetry of the Bay of Fundy

Environmental Setting

The Bay of Fundy is a funnel shaped body of water lying between Nova Scotia and New Brunswick that is famous for its enormous (6-13 m) tidal range (Fig 1). The Bay proper is about 168 km long and about 75 km wide before it splits at its head into Chignecto Bay and Minas Basin. Water depths in the Bay proper range from 20 m at its head to over 100 m at its mouth (Fig 2).

The geology, physiography, sedimentology, and physical oceanography have been described in some detail by Swift and Lyall (1968), Swift et al. (1973), and Fader et al. (1977). The Bay is a glaciated preglacial drainage basin incised into Triassic sandstones, mudstones, and basalts. A Pleistocene glacial drift cover has been reworked to form extensive thin deposits of gravel, sand, and mud in hydraulically suitable locations. The high energy tidal regime of the Bay maintains varying amounts (0.2 mg/l - 65.4 mg/l) of material in suspension (Swift et al. 1973; Kranck 1978 in verb.) that is deposited and eroded from time to time to form and maintain the present sedimentation pattern.

The Bay receives freshwater from 8 major drainage basins. The St. John River is the major contributor (70%) to the Bay and drains the urban and industrial areas of New Brunswick (Fig 1). Second is the St. Croix River that drains the agriculture and lumbering areas of northern New Brunswick and Maine and discharges into Passamaquoddy Bay. On the Nova Scotian side, the Annapolis River and those entering Minas Basin drain the agricultural lands of western Nova Scotia. In addition, dredge spoils from St. John Harbour are dumped 5 km off Cape Spencer. Construction of a nuclear generating station at Point Lepreau adds a potential contamination hazard to the Bay to those already existing along the New Brunswick coast such as pulp mill effluents, municipal sewage, fish processing plants, and cottages.

The potential dispersal pattern of material in the Bay may be inferred from the counterclockwise surface residual circulation pattern of the water shown by Swift et al. (1973) whereas natural and anthropogenic material from Passamaquoddy Bay may follow the clockwise circulation pattern in the Quoddy region that has been determined by a series of drift bottle studies (Chevrier & Trites 1960).

Results and Discussion

Sediment Distribution

Classification of the sediments on the basis of their sand and mud contents provides the sediment distribution pattern that is shown in Figure 3 for material < 2 mm in diameter. Figure 3 shows that sands ($> 95\%$ material > 0.05 mm in diameter and $< 5\%$ material < 0.05 mm) occur in a belt along the Nova Scotian coast, and along the New Brunswick coast, northeast of St. John. Westwards, the mud component in the sediments increases with the result that muddy sands (5-30% mud) occupy the central and offshore western part of the Bay, and very sandy muds (30-70% sand) are found southwest of St. John and in a basin at the mouth of Chignecto Bay. The finest grained sediments sandy mud (5-30% sand) and mud occur off the mouth of Passamaquoddy Bay. They occupy a triangular shaped area that has its base along the New Brunswick coast from a point near the mouth of Passamaquoddy Bay to Point Lepreau and its apex extending to the southeast and lying just (about 10-15 km) off the east side of Grand Manan Island. Within this area referred to as the "Quoddy region" (Forgeron 1959; Chevrier & Trites 1960), the percentage of mud or pelite decreases seaward from the base to the apex.

Table I Bay of Fundy Sediments - Textural Variation of Trace Elements in Total Sample(ppm)

S. Type	No. Samples	Zn	Cu	Pb	Co	Ni	Cr	V	Ba	Hg (ppb)	Cd	As	Se	Be
Sand	17	35	12	15	10	14	49	58	300	30	.12(12)*	9(1)*	.14(5)*	1.2
	Range	18-65	5-26	8-23	4-20	3-39	15-214	27-127	150-540	20-50	.03-.44	-	.12-.16	.8-2.0
Muddy Sand	32	44	13	19	10	12	48	61	290	30	.22	7(8)	.14(20)	1.4
	Range	26-64	8-21	8-30	5-18	4-24	19-220	34-132	230-370	20-50	.07-.52	4-9	.11-.19	1.1-2.2
Very Sandy Mud	21	58	16	20	13	15	68	77	310	30	.23	8(6)	.19(13)	1.7
	Range	42-100	10-32	14-31	7-27	7-46	38-352	51-167	240-390	20-50	.05-.52	5-15	.11-.36	1.3-2.1
Sandy Mud	11	75	19	28	15	22	71	91	350	60	.26	9(9)	.21(9)	2.3
	Range	52-98	15-23	19-35	11-20	14-37	51-91	72-108	220-430	30-90	.19-.35	6-13	.13-.34	1.6-2.9
Mud	2	93	22	40	17	26	82	118	400	70	.15	9	.33(1)	2.5
	Range	81-104	21-23	38-42	13-20	24-27	72-91	99-136	370-430	50-90	.13-.17	7-10	-	2.2-2.8
Average Fundy Sediment	83	51	15	20	12	15	57	70	310	30	.22(78)	8(26)	.17	1.6
	Range	18-104	5-32	8-42	4-27	3-46	15-352	27-136	150-540	20-90	.03-.52	4-15	.11-.36	.8-2.9

* Numbers in brackets refer to number of samples averaged

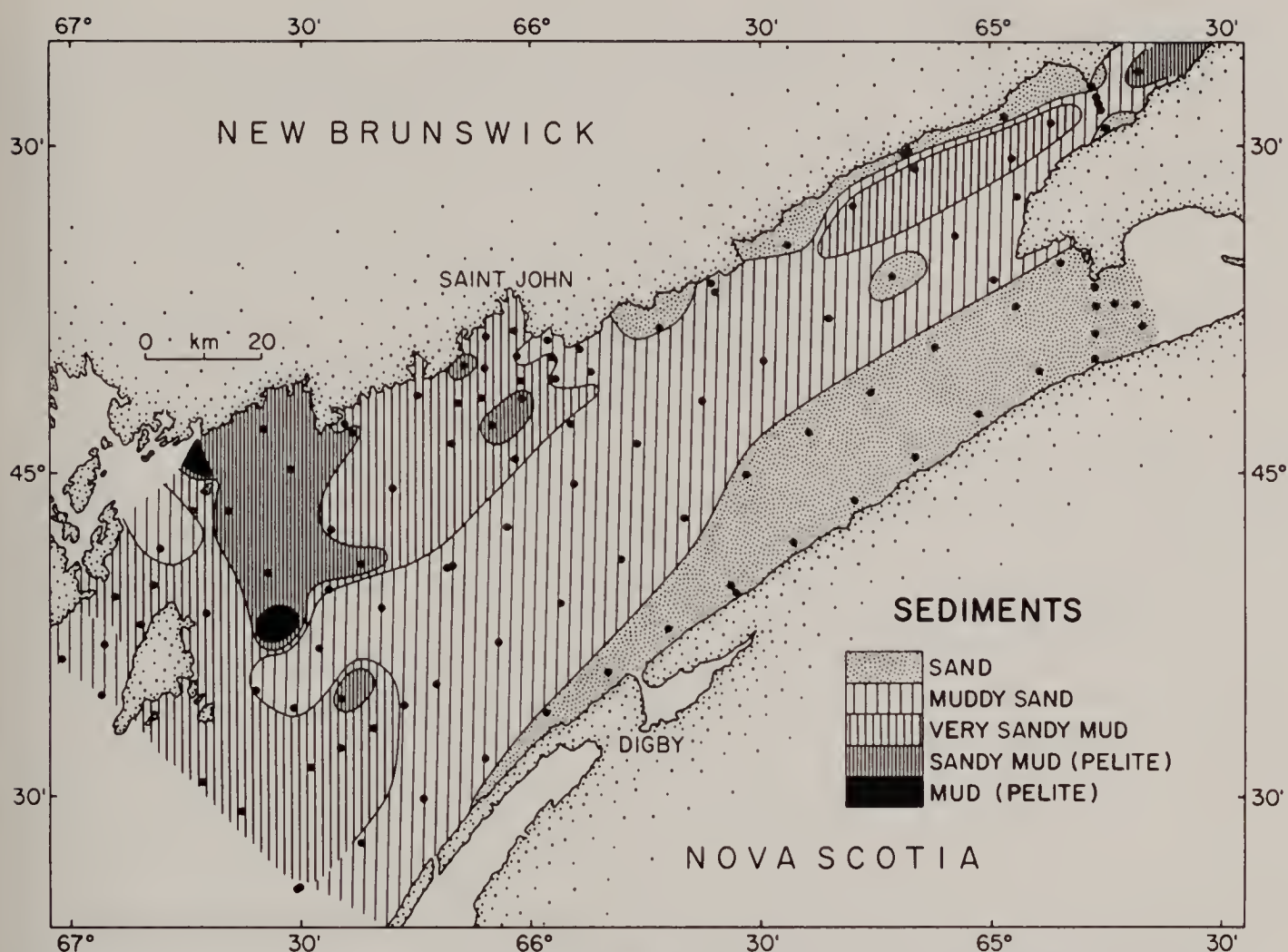


Fig 3 Sediment distribution of material $< 2\text{mm}$ in the Bay of Fundy, nomenclature of Loring and Nota, 1973.

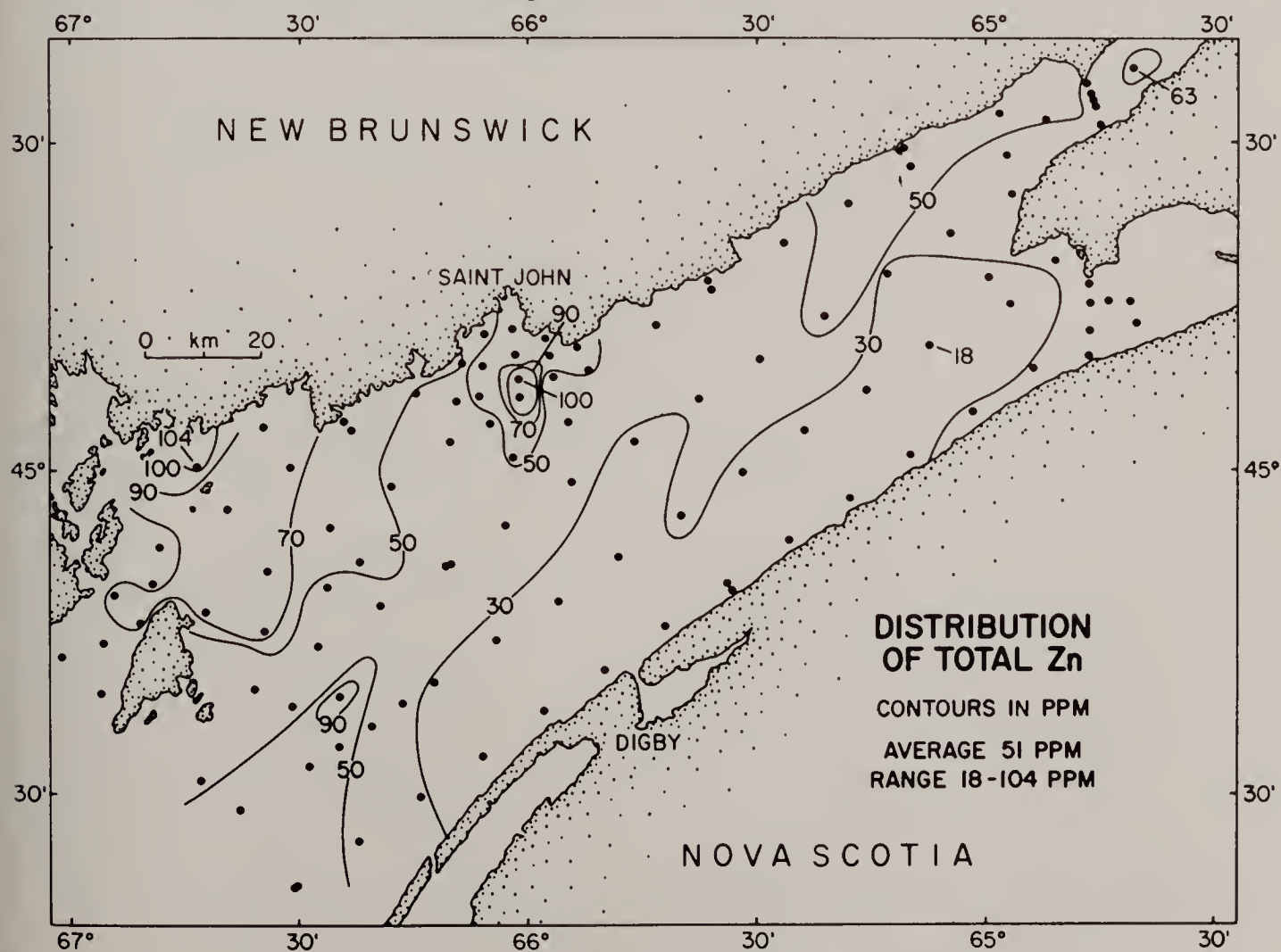


Fig 4 Distribution of total Zn in the surface sediments ($< 2\text{mm}$). Dots show sample locations.

Metal Abundances and Their Relation to Texture

Total metal concentrations measured in the sediments (Table I) show that the average concentrations of Zn, Cu, Se, Pb, Co, Ni, Cr, Be, Hg, and V are low in the sands and increase with decreasing grain size of the sediments so that the highest concentrations occur in the muds. However, the concentrations of As, Cd, and Ba show only slight changes with grain size. Statistical analyses of the data except Pb, Be, and Hg, indicate that the concentrations of Zn, Cu, Co, Ni, Cr, and V increase directly ($r = 0.47-0.83$, $P < 0.01$) with increasing mud content of the sediments. Particle size, therefore, appears to be a controlling factor for the total concentrations of these elements in the sediments and their regional distribution pattern.

Regional Dispersal - Patterns

Because of space restrictions, some but not all of the regional dispersal patterns are shown in Figures 4 to 8. Although they differ in some detail, inspection reveals common dispersal patterns closely related to geographic distribution and the particle size of the sediments. Figure 8 summarizes the geographic distribution of the elements and shows the sedimentary areas containing the relatively high, medium, and low element concentrations. The highest concentrations of Zn (> 70 ppm); Pb (> 30 ppm); Cu (> 20 ppm); Co (> 20 ppm); Ni (> 20 ppm); Cr (> 70 ppm); V (> 90 ppm); Ba (> 400 ppm); Se (> 200 ppb); Hg (> 70 ppb); and As (> 10 ppm) occur in the muddy sands and sandy muds of the Quoddy region. Within this area, most of the elemental concentrations decrease seaward towards the southeast. This pattern suggests a declining source dispersal pattern that follows the surface circulation from Passamaquoddy Bay. Locally, high concentrations of Cr (Fig 5), V, and Ni occur at sites off the west and north coasts of Grand Manan Island. Mercury is an exception to the overall patterns in that it is concentrated in the sediments adjacent to the coast between Passamaquoddy Bay and Point Lepreau (Fig 7).

High concentrations of Zn (94 ppm); Cu (24 ppm); Se (340 ppb); Co (15 ppm); Ni (37 ppm); Cr (80 ppm) and V (103 ppm) also occur at a single site in fine sediments at the mouth of the Bay (Fig 8). Of more importance, however, are the high metal anomalies found near the dredge disposal site off St. John Harbour (Figs 4-8). These anomalies, particularly that of Cd (Fig 6), are a clear reflection of anthropogenic inputs on the local environment and their far-reaching potential influence on other parts of the marine environment of the Bay as evidenced by the dispersal patterns of the elements away from the dumpsite. To the northeast, medium element concentrations occur in the very sandy ($> 30\%$ sand) muds from the basin at the mouth of Chignecto Bay. Medium concentrations of Pb (20-25 ppm) also occur in the center of the Bay (Fig 8). Eastwards the elemental concentrations decline in the sands adjacent to the Nova Scotian coast.

Low concentrations of Zn (< 30 ppm), BA (< 300 ppm), and Se (< 100 ppb) occur in the belt of sands along the Nova Scotian coast, whereas the lowest concentrations of Cr (< 30 ppm), V (< 40 ppm), Ni (< 10 ppm), and Cu (< 10 ppm) occur in the muddy sands from the center of the Bay. It is of importance and interest to note that the concentrations of Cr, V, Ni, and Cu are relatively higher than those found offshore at a number of sites in the sands adjacent to the shoreline of Nova Scotia northeast of Digby. This is believed to result from detrital bedrock material derived from underlying and coastal basalts. Together, the dispersal patterns show the influence of anthropogenic metal inputs to the environment as well as the natural control of particle size on the trace element concentration and distribution.

Comparisons With Other Sediments

Although the abundance and regional dispersal pattern of the trace metals show

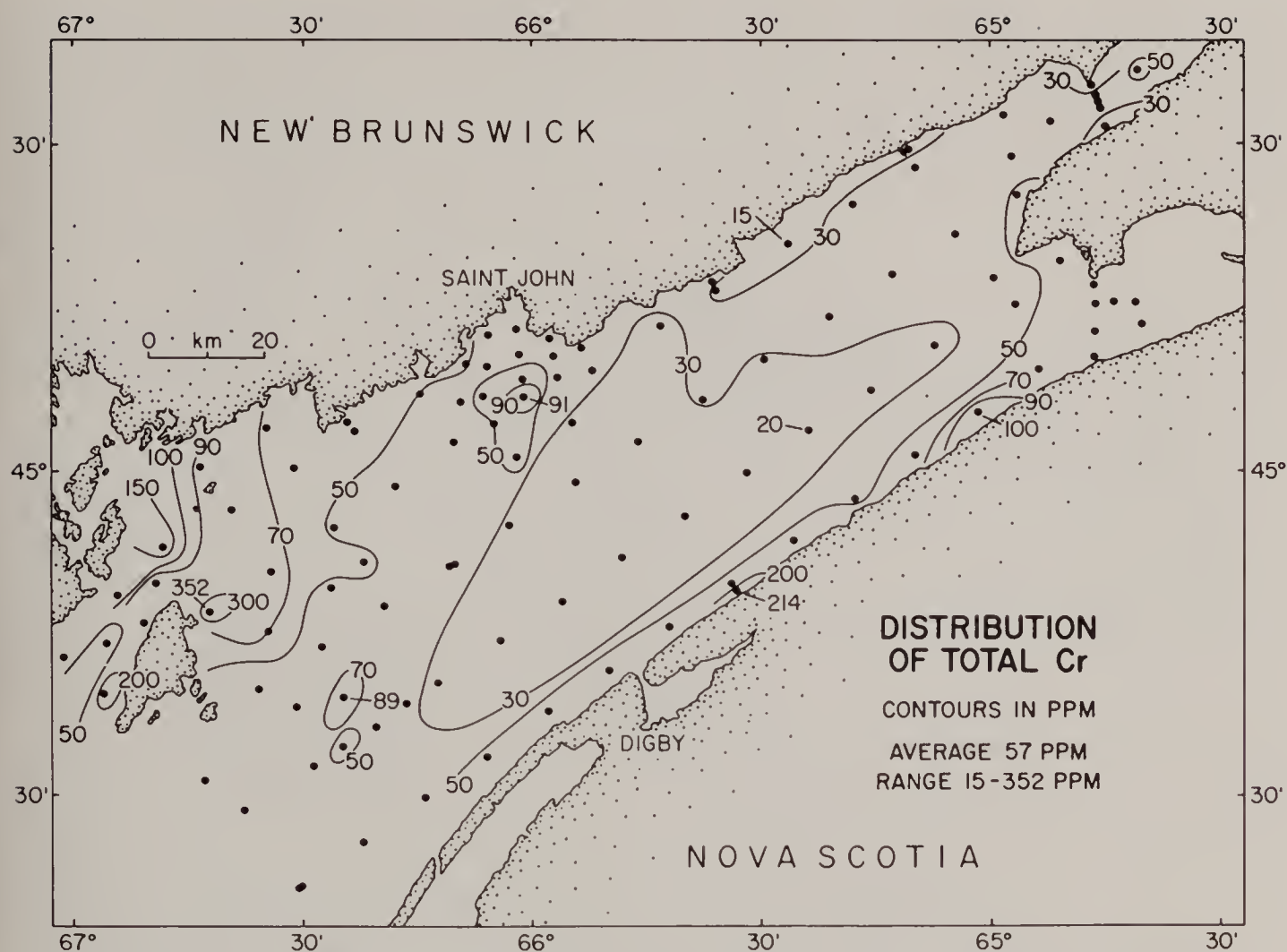


Fig 5 Distribution of total Cr in the surface sediments (< 2mm).

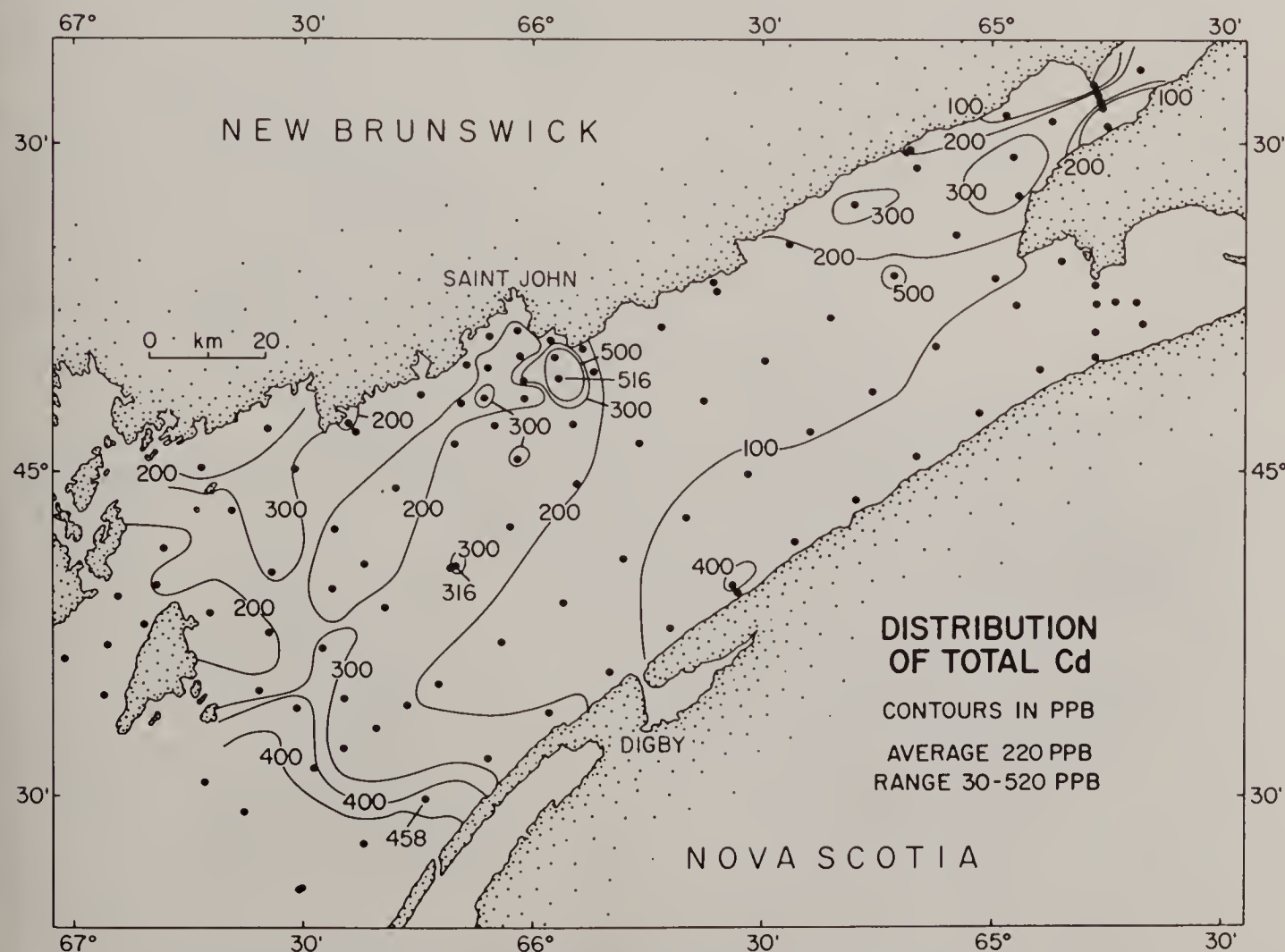


Fig 6 Distribution of total Cd in the surface sediments (< 2mm).

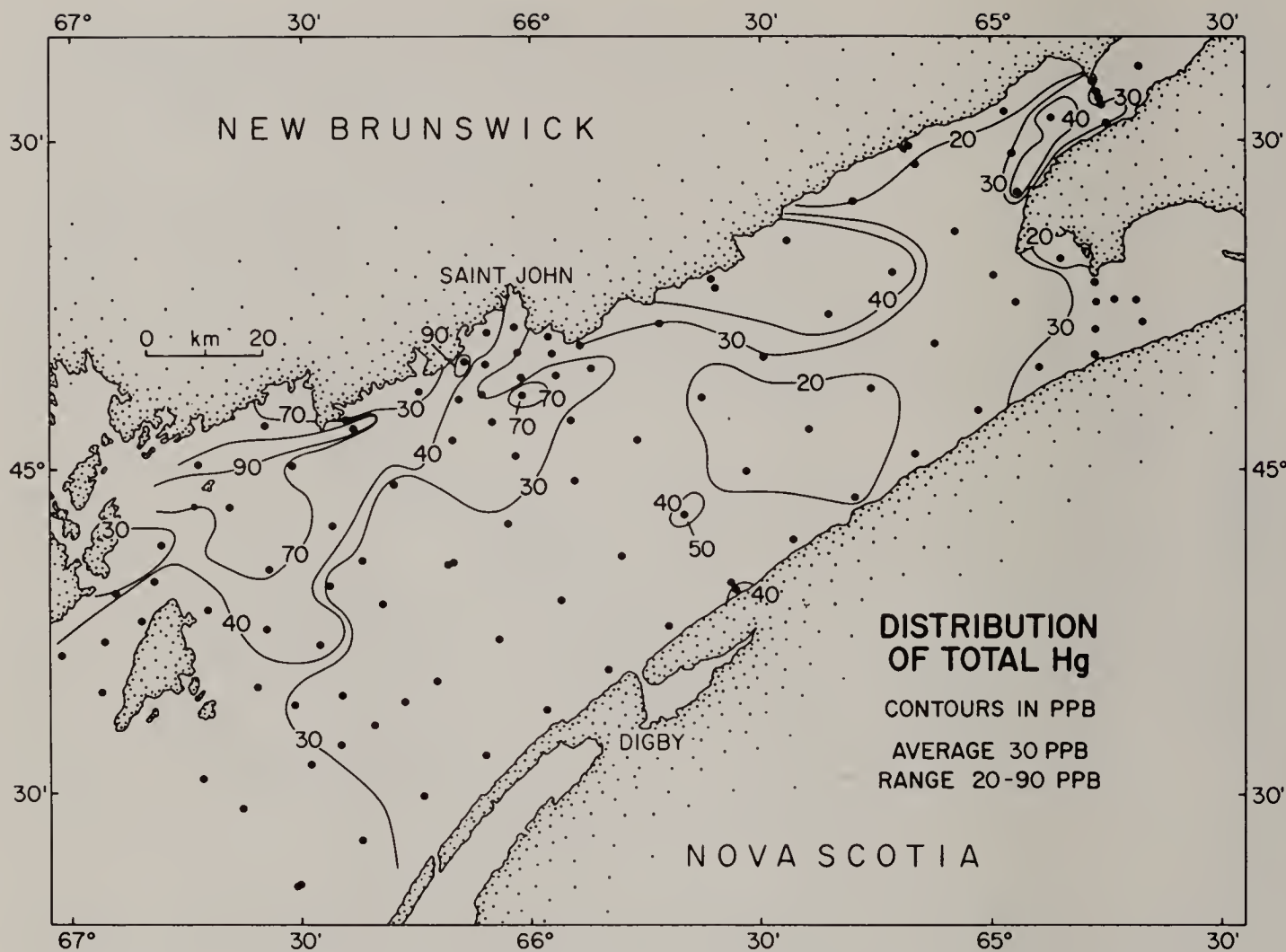


Fig 7 Distribution of total Hg in the surface sediments (< 2 mm).

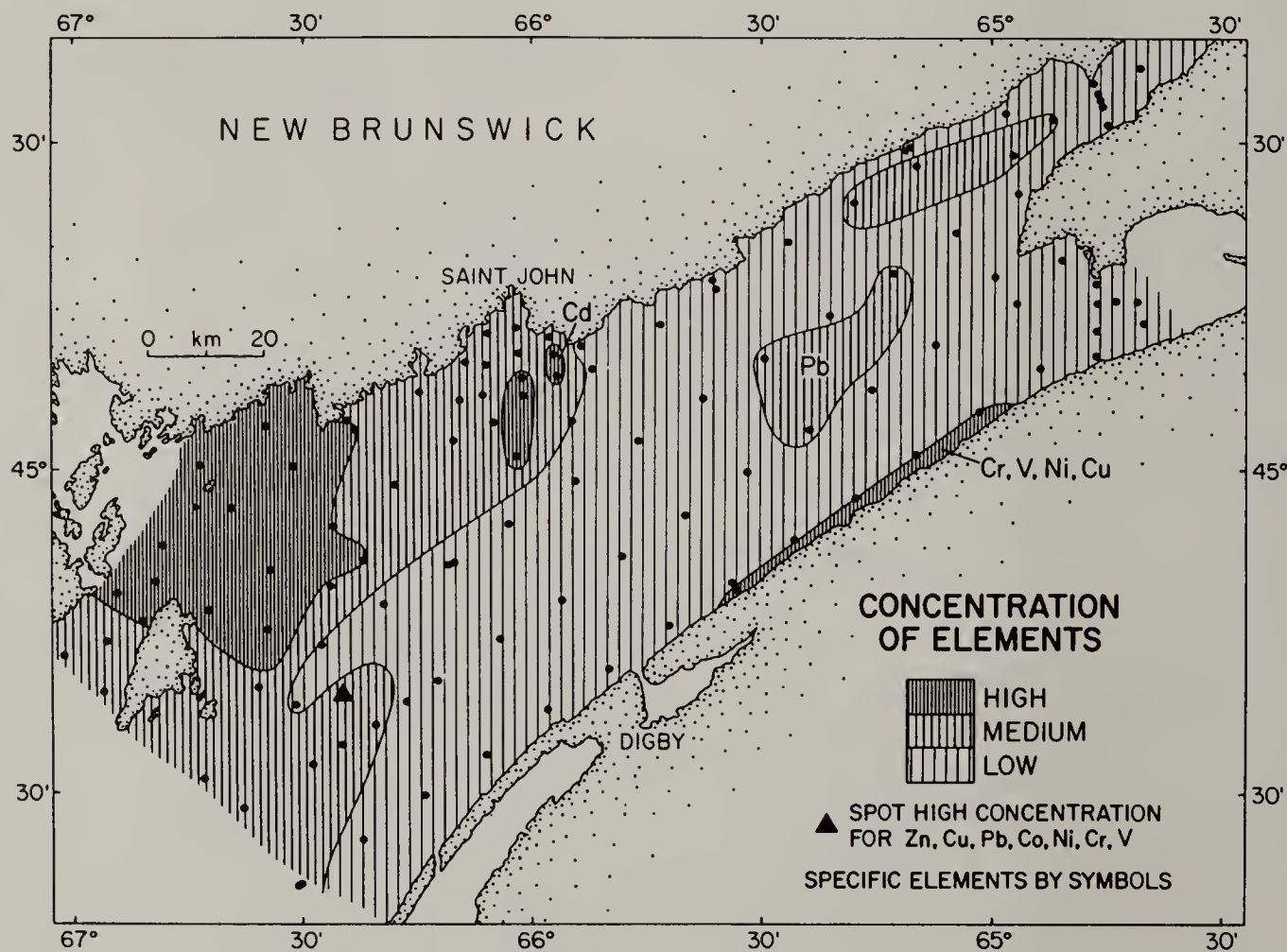


Fig 8 Distribution of the relatively high, medium, and low concentrations of Zn, Cu, Pb, Co, Ni, Cr, V, Be, Ba, Se, Hg, and Cd in the surface sediments (< 2mm).

small, but significant anthropogenic influences, it is of utmost importance to assess them in relation to the levels found elsewhere. Since the elemental concentrations vary with particle size, it is essential that comparisons be made with texturally equivalent sediments when possible. Table II compares the elemental concentrations of the fine-grained Fundy sediments with those found in various parts of the Gulf of St. Lawrence, and polluted and unpolluted sediments from the United Kingdom and the Netherlands.

The Fundy muds contain lower concentrations of Zn, Cu, Ni, Cr, and Hg, than those of the St. Lawrence Estuary (upper and lower) and the Saguenay Fjord. The Zn concentrations of the Fundy muds are comparable with, and the concentrations of Cu and Ni are lower than, those of the open Gulf and Placentia Bay sediments. Fundy Pb concentrations are, however, higher than those from the open Gulf and comparable to those values found in the St. Lawrence estuary. Co concentrations are comparable to all parts of the St. Lawrence region. V concentrations are comparable to those found in the upper St. Lawrence estuary, but lower than those from other parts of the St. Lawrence system. Arsenic concentrations of the Fundy muds are also much lower than those of the Saguenay Fjord sediments, but are comparable to the other parts of the St. Lawrence region.

Thus, there is no indication that the fine-grained sediments are particularly high in the metals; rather most are lower when compared with texturally equivalent sediments from the St. Lawrence system. A possible exception is Pb, which is concentrated in the fine-grained Fundy sediments and is comparable in concentration to polluted sediments of the St. Lawrence estuary (Loring 1978).

When compared with unpolluted sediments from other outside areas, Table II indicates that Fundy pelites contain comparable or slightly higher Zn, Cu, Co, Cr, and Pb concentrations than the unpolluted sediments of Solway Firth, and V and Cr concentrations comparable to those reported for sediments of the Severn estuary. In contrast the Fundy elemental concentrations are much lower than those reported for the very polluted sediments from the Firth of Clyde, Clyde estuary, and Severn estuary (except Co, V, Cr). Thus, Fundy sediments contain trace metal levels comparable to those found in unpolluted sediments from other parts of the world. This is not to say that the natural levels of trace metals have not been altered, but rather than the anthropogenic inputs of heavy metals have not yet reached significant levels, although they may do so in the future.

Conclusions

Particle size is the main factor controlling the abundance and distribution of the total trace metal concentrations in the Bay of Fundy. This is because detrital host minerals are mostly fine grained except those of Cr, V, and Ni and the absorption of the metals onto particles increases with their surface area. The finer offshore sediments of the Quoddy region are a sink and an enrichment area for total trace metals. These are supplied in particulate and perhaps dissolved form from natural and industrial sources. The most likely anthropogenic sources are the St. Croix drainage basin, the coastal industries, municipalities between Passamaquoddy Bay and Point Lepreau, and the offshore dredge disposal site. Any material discharged from the proposed nuclear generating station at Point Lepreau may also end up in this sink depending of course on the depositional conditions at the time of discharge.

At present, the average levels of trace metals in the Fundy sediments, perhaps with the exception of Pb, are at or near natural levels found in unpolluted fine-grained sediments. This is not to say that this will not change as the data clearly

Table II Average Total Elemental Concentrations in the Fine Sediments of the Bay of Fundy Compared to Those Found Elsewhere

Location	No. of Samples	Zn	Cu	Pb	Co	Ni	Cr	V	Hg (ppb)	As	Cd	Se
Bay of Fundy	13	77	19	30	15	22	73	95	60	9(11)*	.24	.22(10)
Upper St. L. Est. a,b	3	185	36	34	15	27	92	97	380	6(2)	.26	.56
Lower St. L. Est. a,b	29	115	24	30	17	33	99	110	449	7(27)	.22	
Open Gulf of St. L. a,b	71	84	25	21	14	36	87	105	221	6(62)	.26	
Saguenay Fjord c,d	13	130	27	48	16	28	83	121	3660	21(11)	.25	.51
Placentia Bay Nfld. e	28	80	34	32	16	41	53	-	-	-	-	-
Severn Est. f	-	280	38	119	7	36	71	86	-	-	1.9	1
Firth of Clyde g	-	165	37	86	34	50	64	-	-	-	3.4	-
Clyde Est. g	-	1680	225	528	60	69	624	-	-	-	-	-
Solway Firth h	-	63	10	37	16	38	35	-	-	-	2.9	-
Gulf of Paria i	-	-	17	22	8	31	93	130	-	-	7	-
Rhine River j	-	2400	300	530	-	48	640	-	10000	200	13	-

aLoring 1978; bLoring 1979; cLoring 1976a; dLoring 1976b; eWilley 1976; fChester and Stoner 1975; gMackay et al. 1972; hPerkins et al. 1973; iHirst 1962; jDeGroot et al. 1974.

*Numbers in brackets refer to number of samples averaged.

show that small, but significant anthropogenic inputs are having an effect on the natural levels of the metals in the sediments.

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SOME OBSERVATIONS ON THE RELATIONSHIPS BETWEEN HIGH TIDE LEVELS AND COASTAL RESOURCES IN CUMBERLAND BASIN

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Relationships between high-tide levels in Cumberland Basin and the dykes, aboiteaux, and salt-marsh communities were observed during exceptionally calm conditions. During the large tide of 20 June 1978, the high-water levels reached +6.89 m to +7.37 m above mean sea level. During the small tide, which followed on 26 August 1978, the corresponding elevations were +4.39 m to +5.01 m above mean sea level. Saltmarsh communities extended as high as +6.83 m above mean sea level during the indicated growing season. Further study concerning the distribution controls of local halophytes is suggested. Additional related observations, on stream controls and a drowned forest of scientific interest, are included.

Introduction

Cumberland Basin is one of several potential areas for Fundy tidal power development, and as such is commonly referred to as "A8". Although studies concerning the mega-tidal behavior in this area continue, the implications of altered tides because of barrage construction are not well understood.

Most of the tidal marshlands surrounding Cumberland Basin are protected now from all but the highest levels of seawater by dykes and aboiteaux. The earliest dykes were constructed 3 centuries ago, their remnants being diminutive compared with the modern machine-made earthen dykes. The modern dykes around Cumberland Basin are built to a nominal elevation of +8.4 m above Geodetic (Survey of Canada) Datum*, giving freeboard protection from normal high tides of about 0.6 m. The aboiteaux on the tidal streams with their one-way 'flapper gates' also are now built with modern equipment to provide freshwater drainage to about 1.8 m below the backshore surface.

Inside the dykes and aboiteaux there are extensive tracts of arable land, divided into various administrative and/or co-operative units known as Marsh Bodies. The Marsh Bodies are distinguished officially by common names and number codes. Outside the dykes, saltmarsh communities stabilize and protect some parts of the intertidal zone. Elsewhere, foreshore sediments and exposed bedrock contribute to the high suspended sediment load of Cumberland Basin.

The slopes of the intertidal zone and backshore vary greatly around the Basin and are being studied in detail by the Chignecto Research Group of Mount Allison University. Certainly, on the shallow gradient vegetated slopes, a hypothetical change in the tidal regime could have a measurable impact on the distribution of saltmarsh communities. It is also possible that an altered tidal regime could affect the freshwater discharge through the aboiteaux.

The primary objective of this study is to begin an investigation of the magnitude of a tidal change which probably could be tolerated by the coastal resources of Cumberland Basin.

*Geodetic Datum is considered here to be equivalent to contemporary mean sea level, a universal reference.

Methods and Techniques

My basic assumption is that the contemporary distribution of plant communities, dykes, and other features of Cumberland Basin has a definite relationship to the present tidal regime.

An assessment of the contemporary elevations of coastal resources began with an examination of the Marsh Plans held by Maritime Resource Management Service (M.R.M.S.) in Amherst, N.S. Typical spot elevations were noted for land surfaces inside (and sometimes outside) the dykes which are recorded directly on the Marsh Plans. Additional comments by members of the Engineering Division of M.R.M.S. were also noted.

The most current survey values for monuments in the area were obtained from Land Registration and Information Service (L.R.I.S.), Summerside, P.E.I. These data were used in planning a field program, as well as in the final computations. Furthermore, members of the Chignecto Research Group of Mount Allison University offered an opportunity for this work to be integrated with their field studies; these included systematic tidal observations around Cumberland Basin during a large tide on the 20th of June and during a small tide on the 26th of August. These tides were predicted to be close to the extreme high tidal levels for 1978 and should be related to the uppermost limits of the saltmarsh communities.

In the course of the tidal observations, the uppermost water levels were marked by stakes. During the large tide, 12 different sites were marked (Fig 1). Ten different observations were available for the small tide, a reduction reflecting manpower limitations.

The elevations of the high water markers were tied by spirit levelling to the nearest survey monuments of known elevation. Under the time constraints, it was not possible to run 2 completely independent (check) lines for all the markers. Therefore, 2 distinct lines were levelled simultaneously using the same instruments and the respective values were computed as 2 separate lines. All the computed metric elevations for the high water markers are presented here as the means of 2 independent or quasi-independent observations. The field observations were initially made in English units, estimated to the third decimal of a foot, and averaged in the technique of "three-wire levelling".

Several survey lines were very short, but the longest exceeded 5 km linking Bore View Park at Lower Macan to a reference at Lower River Hebert. Whenever convenient, observations were made on the limits of the lower marsh communities (e.g. *Spartina*). In addition, a spur line was levelled across the upper marsh (e.g. *Juncus*) surface east from the Fort Beausejour station for several reasons: 1) to collect a sequence of typical elevations of the permanent marsh surface; 2) to obtain the elevations of the brackish ponds on the marsh surface where some waterfowl feed; and 3) to ascertain the contemporary elevations of the stumps in the drowned forest (Fig 1).

Observations

High Water Levels

It was particularly remarkable and fortunate that both sets of tidal observations were made under conditions of *minimal* wind influence. The calm water surfaces made accurate placement of high water stakes feasible. The figures thus indicate the *least levels* to be achieved during extreme tides. (Because of fetch, etc., slightly windy conditions would probably raise these levels measurably). The high water levels are given in Table I.

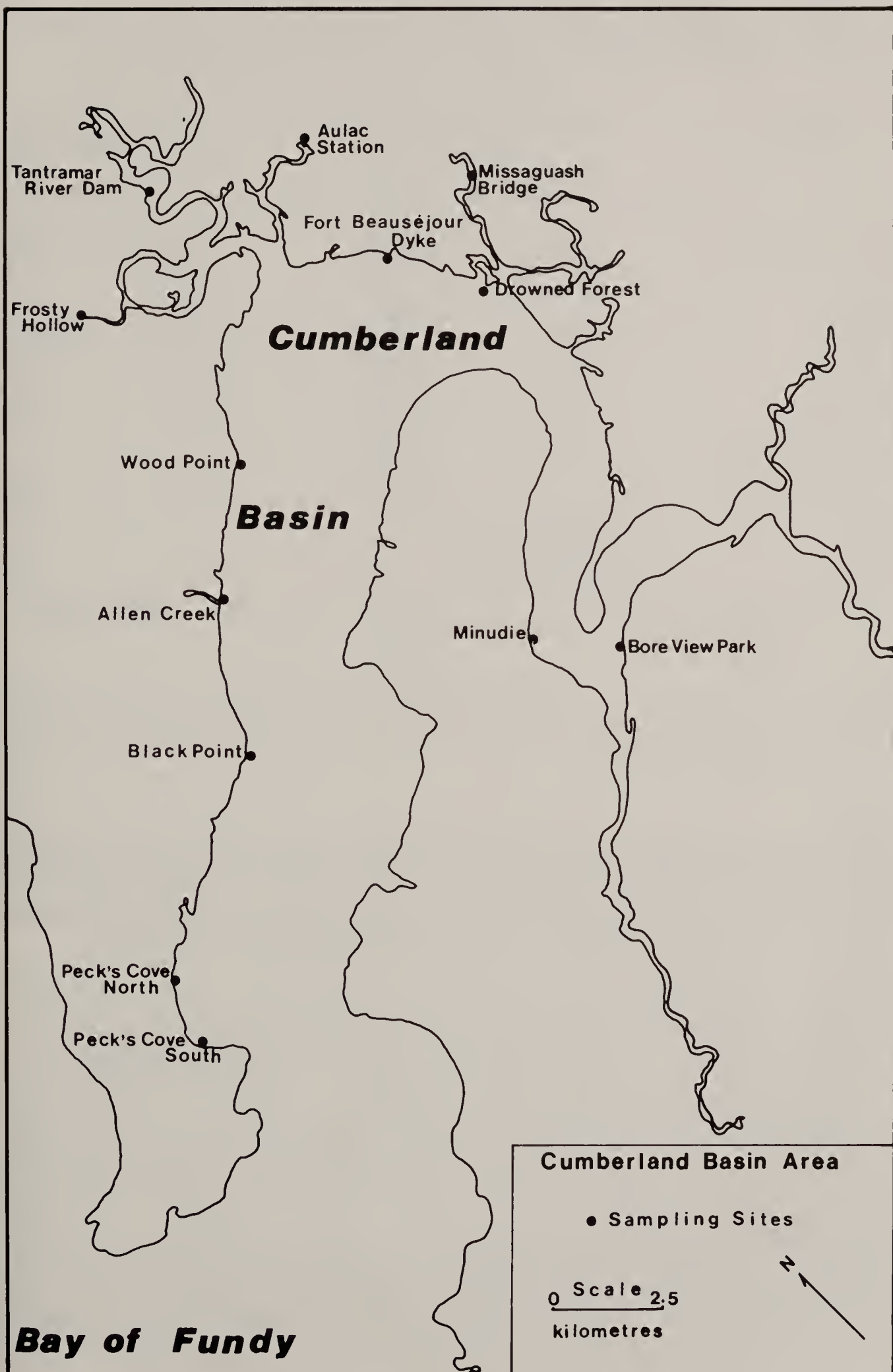


Fig1. Map showing the locations of sites discussed in text.

Table 1: Observed mean high tide levels, Cumberland Basin, 1978 (meters above mean sea level/Geodetic Survey of Canada Datum). Elevations derived from twelve levelling traverses.

Station	Large Tide (20 June)		Small Tide (26 August)	
	Mean	SD	Mean	SD
Peck’s Cove South	6.89 m	0.00	4.44 m	0.00
Peck’s Cove North	6.74 m	0.00	4.39 m	0.00
Black Point	6.94 m	0.03	4.46 m	0.05
Allen Creek	6.97 m	0.01	4.56 m	0.01
Wood Point	7.03 m	0.00	4.57 m	0.01
Frosty Hollow	7.35 m	0.01	5.09 m	0.02
Tantramar Dam	7.30 m	0.01	4.82 m	0.00
Aulac Station Dyke	7.10 m	0.03		
Fort Beausejour Dyke	7.10 m	0.01	4.73 m	0.01
Missaquash Bridge	7.12 m	0.02	4.81 m	0.01
Minudie*	7.31 m	?		
Bore View Park	7.37 m	0.01	5.01 m	0.01

*Minudie value provided by Chignecto Research Group.

Each high water stake has a corresponding elevation relative to mean sea level. Each stake can be used as a local reference datum for ascertaining the elevations of proximal saltmarsh communities.

Salt Marshes

All of the large tide high water levels were observed to exceed the elevations of the saltmarsh communities. Observations are available for the crest and foot of various *Spartina* marsh communities and one large *Juncus* marsh at Fort Beausejour Dyke. The observations on saltmarsh communities are indicated in Table II.

Aboiteaux and Tidal Dams

Most of the former tidal streams debouching into Cumberland Basin now have control structures to prevent tidal water from “back-flooding” the channels.

The stream controls have dimensions as small as 0.3 m x 0.3 m or may be even larger than the Tantramar River Dam with two sluices each 4.6 m x 4.9 m.

Most of the aboiteaux are top-hinged in such a manner that once the tide falls, the freshwater can drain out simply because of the head developed behind the gate. The vertical sliding gates at the Tantramar River Dam are, however, electrically operated by an attendant who monitors the freshwater impoundment regularly. The sill elevation of the sluice at this dam is at -4.6 m mean sea level. Freshwater discharge begins during ebb tide when sea water levels fall below -1.6 m. (C. Desplanque, in verb.). Discharge continues as sea water levels fall below the sill at -4.6 m.

Drowned Forest

On the intertidal slope near the mouths of the Missaquash and LaPlanche Rivers lies a drowned forest. In the event that this scientific site would be rendered inaccessible for interested parties and future research, some elevations were

Table II: Observed saltmarsh levels, Cumberland Basin, 1978 (meters above mean sea level/Geodetic Survey of Canada Datum). Elevations derived from single observations near high tide markers.

Location	Upper Limit	Lower Limit
Peck's Cove		4.38 m
Wood Point	5.78 m	4.53 m
	6.72 m	
	5.84 m	
Fort Beausejour Dyke	6.06 m	
	5.80 m	
	5.69 m	
	5.75 m	
	5.62 m	
	5.70 m	
	Tidal Pond 5.49 m	
	Tidal Pond 5.72 m	
	Old Dyke 6.25 m	
Bore View	6.66 m	5.42 m
	6.79 m	5.04 m
	6.83 m	4.87 m
	6.45 m	5.37 m
	6.37 m	4.59 m
		4.34 m

Table III: Observed elevations of Drowned Forest Stumps, Cumberland Basin, 1978 (relative to mean sea level/Geodetic Survey of Canada Datum). Elevations are derived from single observations in a loop traverse with a total closure error of 0.05 m.

Ground Elevation adjacent to selected stumps:		
-0.28 m	-0.24 m	-2.07 m
-0.35 m	-0.36 m	-1.69 m
-0.57 m	-1.24 m	-0.41 m
-0.46 m	-0.91 m	

determined for this drowned forest. A short spur line was extended from the Fort Beausejour Dyke line to ascertain the appropriate elevations presented in Table III. In general, the stumps lie now on a winnowed gravel surface. The root crowns are firmly lodged in the substrate and are commonly believed to be in situ. They are found slightly below mean sea level in this locality (-0.24 m to -2.07 m).

Discussion and Conclusions

The results of spirit levelling from L.R.I.S. monuments to appropriate high water stakes and saltmarsh communities have been tabulated. It can be seen in a comparison of the observed high water levels and upper marsh

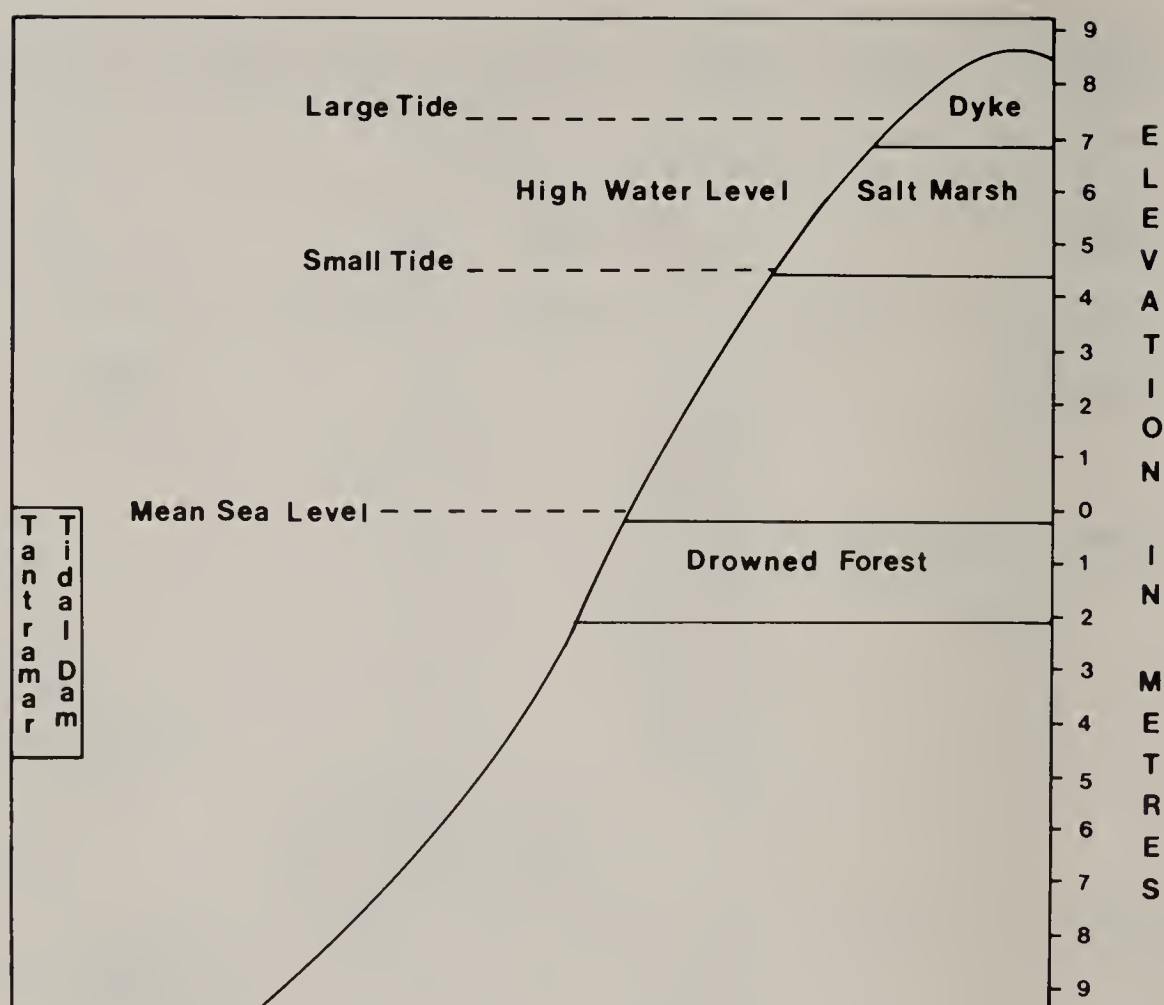


Fig 2. Hypothetical shore profile showing vertical relationships of subjects discussed.

limits that the large tide high water level exceeded the observed growth limit by at least 0.31 m. Under more typical conditions, the high water levels are probably higher because of the local meteorological and hydrographic conditions. Precisely how much this flushing could be altered without substantial vegetational repercussions is undetermined; the requirements of the halophytes in this locale should be studied further.

With regard to stream drainage and water control, apparently the lowest sluice sill on Cumberland Basin is that of Tantramar River Dam at -4.6 m elevation. Provided that the low tide falls below that depth, freshwater drainage could probably be effected properly.

The continued access to the drowned forest in Cumberland Basin is of importance. Because the tree stumps in question lie between -0.24 m and -2.07 m, they would be rendered inaccessible only in the most severe and catastrophic tidal alterations.

The relationships of the salt marshes, Tantramar River Dam, and drowned forest to the dykes and tides are illustrated (Fig 2).

It can be seen that a change of a few decimetres would not be expected to have extensive implications for the resources discussed herein.

Acknowledgements

I am indebted to Mr. Greg Langille for field assistance and to the Chignecto Research Group at Mount Allison University for support. Most of the staff of the Engineering Division, Maritime Resource Management Service made important comments, as did representatives of Nova Scotia Department of Agriculture and Marketing, and New Brunswick Department of Agriculture and Rural Development.

OBSERVATIONS ON SALTMARSH POOLS, MINAS BASIN, NOVA SCOTIA 1965-1977

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Two pools in the salt marshes of Kings Co., Minas Basin were studied from October 1965 to January 1967. Changes in temperature, salinity, ice cover, and floral and faunal composition were recorded. Relevant information gathered during subsequent field trips 1967 to 1977 has been added, and from this accumulated data several significant fluctuations in population density, local distribution, and maximum body size were discerned for 3 species of sacoglossan molluscs, 1 species of anemone, and 2 species of nemerteans.

There were irregular time periods when the tidal waters did not reach the study pools, the longest being 25 days. The highest water temperature recorded was 28.5° C and the lowest -1.5° C. Tidal water entering the pools had a salinity of near 29‰ whereas average salinity at the bottom of the two pools was 33.4 ‰ and 32.4 ‰. The average surface salinity was 31.4 ‰ and 30.2 ‰. Salinities below 20 ‰ were unusual and only the pool surface water ever reached the minimum recording of 11.1 ‰. Thus, these permanent saltmarsh pools are rather unusual lentic marine habitats, scarcely influenced by coastal marine temperatures, tides, or currents.

Ice formation is irregular but can cover these pools for periods exceeding 3 months. Measurements of ice thickness from 7 winters ranged from 19 cm to 68.5 cm. Nevertheless, algae remain green and many animals are active throughout the winter beneath substantial ice and snow covers.

The dominant species of macrofauna were 1 anemone, 2 nemerteans, 3 gastropods, 1 amphipod, 2 insects, and 1 fish.

Introduction

The initial examination of saltmarsh pools in Minas Basin by Acadia University staff and students began in 1965. Some of the subsequent accumulation of data has been published (Bailey & Bleakney 1966; 1967; Bleakney & Bailey 1967; Bleakney 1972; Frank & Bleakney 1976; 1978; Graves et al. 1979) but much information has remained in thesis form. With the current interest in Bay of Fundy environments and the desire to establish base line data for future comparisons, it was felt that our data should be made available through an appropriate journal. The purpose of this paper is to present information from theses, reports, and field notes which can contribute to our understanding of the physical and biotic features of Minas Basin marshes.

Although the literature concerning salt marshes is vast, saltmarsh pools have been largely ignored. Bromley and Bleakney (1979) compared reports from United States (Teal & Teal 1969; Nixon & Oviatt 1973) and British Isles (Hickson 1929; Lebour 1931; Nicol 1933; 1935; Brough et al. 1960) with Minas Basin marsh pool faunas. The evident relative paucity of species in other areas (Nixon and Oviatt, 14 species; Brough, 31 species) as compared with 76 taxa for Minas Basin (Bromley & Bleakney 1979) may help explain the lack of interest by estuarine biologists in other parts of the world.

Our local marsh pools are unusual qualitatively as well. Several of the most important marsh organisms in eastern United States such as ribbed mussel (*Guekensia demissa*), marsh snail (*Melampus lineatus*), and various crabs are absent or extremely rare in Minas Basin. However, other rare and unusual organisms such as the sacoglossan molluscs (*Alderia modesta*, *Elysia chlorotica*, and *Stiliger fuscata*), the

burrowing anemone (*Nematostella vectensis*), and viviparous nemertine (*Prostomatella obscura*) are often abundant.

One of the characteristic features of these pools is the development of dense mats of filamentous algae in which reside many of the marsh pool animal species. Our first general survey in 1965 concentrated on determining the faunal community within these algal mats and the physical parameters of temperature, salinity, and ice formation.

Literature Review

In his study of the Minas Basin, Ganong (1890) failed to mention saltmarsh pools entirely and his later Bay of Fundy marsh report (Ganong 1903) referred briefly to the absence of life in marsh pools except for "a few simple algae". Bousfield and Leim (1960) devoted one sentence to pool inhabitants including *Gammarus mucronatus* and *Orchestia grillus*, a small corixid bug, the snail *Hydrobia totteni*, but beyond this their composite list of marine fauna of the Minas Basin lacks most of the pool fauna. Chapman (1937; 1960) summarized Ganong's previous findings adding some of his own observations on the Wolfville marshes but, as with Ganong, the emphasis was on the flora. The 1976-78 survey by Bromley (Bromley & Bleakney 1979) was limited to benthic organisms occurring in the soft sediments of marsh pools.

Study Area

Hydrographic details of Minas Basin were reported by Bousefield and Leim (1960), and local saltmarsh origin and build up was described by Ganong (1903). Minas Basin is a shallow, triangular body of water connected with the Bay of Fundy by the S-shaped Minas Channel. The red sand and mud so characteristic of the Basin were formed from an erosion of the Carboniferous and Triassic sandstone substratum. Tides having extreme ranges of 16 m make the Basin unique in this respect. This surge of tidal waters results in a heavy suspension of inorganic silt which is dropped by the check of the tide's quiet spread over the marshes. The extensive algal mats which develop over the mud in the *Spartina alterniflora* zone can be completely encased by 2 to 3 mm of red clay deposit on a single spring flood tide. In winter blocks of drift ice carry much clay, and often gravel and shells and even large basalt rocks. Many of these ice blocks, which average 1 m in thickness, are deposited on the marshes and marsh pools where they eventually melt leaving conspicuous mounds of sticky red clay. The larger Minas Basin ice blocks of 5 to 6 m thickness cannot be floated over the marsh, and thus their massive loads of entrapped sediments are simply returned to the muddy slopes of the creeks and flats. Ice can build up on the marshes and then be floated off by spring tides, tearing out the *Spartina* grasses. This bottom coating of *Spartina* on the ice sheets gradually works its way upwards through the ice (Medcof & Thomas 1974). The same block may ground several times on the marsh in the course of a winter season, and we have photographs on file showing 3 successive layers of *Spartina* within a 1 m-thick block of drift ice. If such a block settles on a marsh pool considerable organic detritus is added to that pool when the block melts.

The principal study area of 1965-67 was located along the Habitant Creek estuary southeast of Canning, Kings Co., N.S., in a *Spartina patens* and *S. alterniflora* marsh next to the old pilings of Pickett's Wharf (Fig. 1). Habitant Creek is dyked to the west of the saltmarsh area and fresh water flows out through an aboideau only at low tide, some 6 m below the level of the marsh. The marsh extends in width about 250 m from the adjacent roadbed to the creek bank at the wharf pilings.

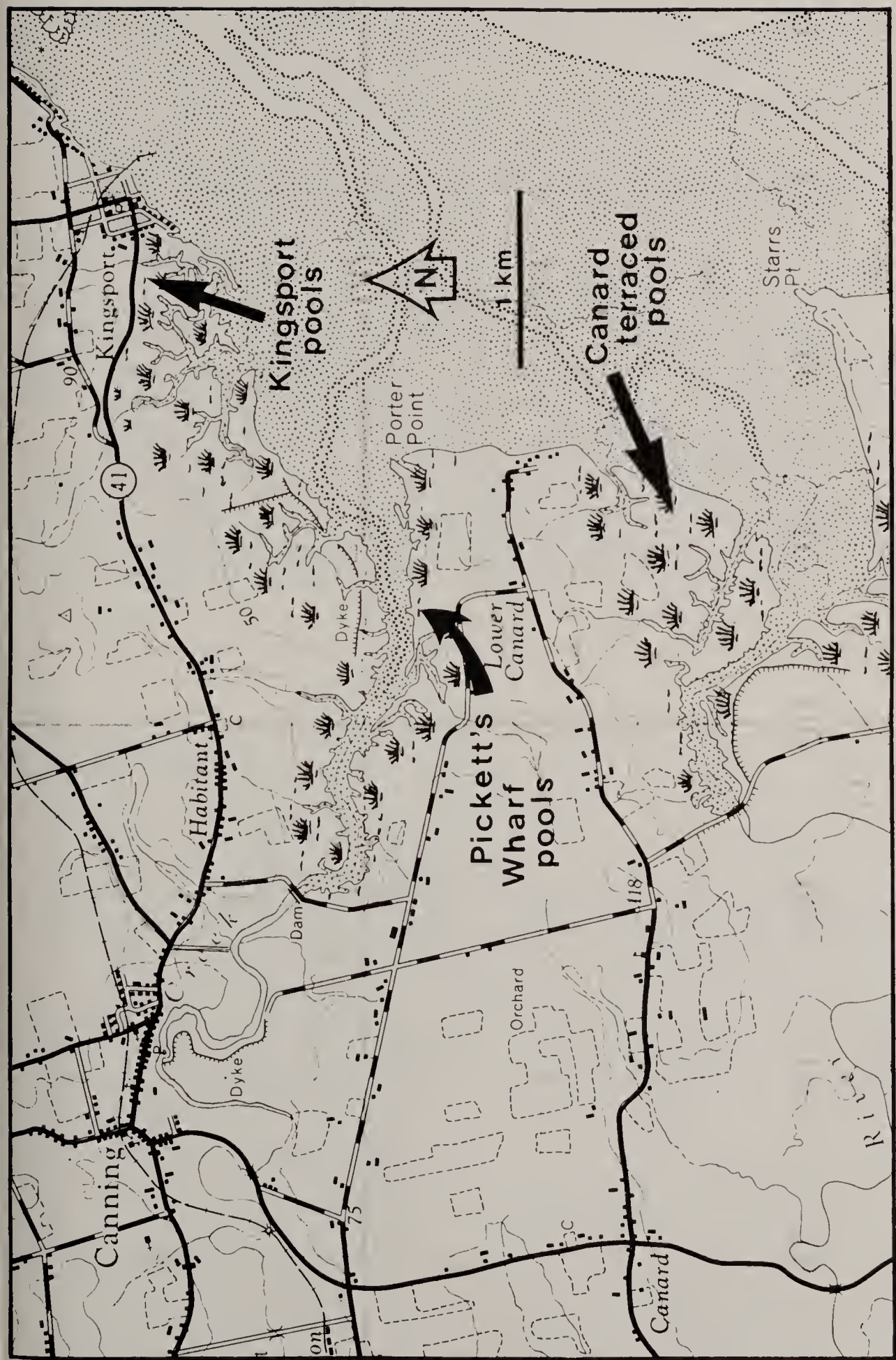


Fig 1. Topographic map of southwestern Minas Basin, Nova Scotia, showing location of principal study site at Pickett's Wharf and areas in Canard marsh and Kingsport marsh referred to in the text.

The 2 pools studied were immediately south of Pickett's Wharf. Pool No. 1 measured about 13 x 3 x 0.6 m. The northeast bank was steep, sandy and vegetated by *S. patens* (Fig 2). The southeast end of the pool was quite shallow (7.5 - 15 cm) and the tide entered here as it came through a small channel in the sand. The west bank merged gradually with the *S. alterniflora* and the tides also entered at this side of the pool.

Pool No. 2 was 32 m southwest of Pool No. 1 and was 30 cm higher thus being flooded less often by the tides. It measured 12.2 x 7.6 x 0.8 m with well defined banks except on the north side where it merged into the marsh and where the tidal waters entered. It was surrounded entirely by *S. alterniflora* (Fig 3).

Flora

The vegetation of Pool No. 1 was primarily *Cladophora*, *Chaetomorpha*, and the halophyte *Ruppia maritima*. However, distribution of these was not uniform. At the northwest end of the pool was *Chaetomorpha*; *Ruppia* occupied the western side; and *Cladophora* dominated the southern and central sections. The substratum was a black ooze rich in anerobic sulfur bacteria. In Pool No. 2 *Ruppia* occurred in scattered patches, but the algal covering was rather different. *Oscillatoria* dominated and was woven into felt-like mats with *Cladophora* and *Chaetomorpha*. On sunny days, with increased oxygen production, these mats rose to the surface in patches and partially or completely covered the pools. During dark dull days, they remained on the bottom. In Pool No. 2 the bottom was also the typical ooze, sometimes spotted by blooms of pink sulfur bacteria.

When high spring tides inundated the marsh, the study pools were momentarily covered by 0.4 to 0.6 m of water. Depending on the degree of wind action, this flooding had 2 effects. One was the deposition of silt as a thin layer over the pool vegetation. If there was little wind action on subsequent tides, this coating of clay remained undisturbed. The second wind effect was the dramatic removal from the pools through wave action of all free-floating algal mats. As these were washed away and the tide receded, they became entangled in marsh grass and soon were baked by the sun. Most of the contained fauna were also trapped and desiccated and scavenging marsh amphipods took over. After one such combination of factors in late June 1966, Pool No. 1 was surrounded by sheets of dry algae varying from 0.3 to 3.4 m² in area. The *Ruppia* plants, being firmly anchored, helped retain some of the filamentous algae and this served as a nucleus for replenishing the pool algae.

The algae made a feeble recovery from this washout in June only to die down during July, August, and September in Pool No. 1, but by October 17 the growth had recovered. Pool No. 2, however, maintained its algal coverage all summer until September 20 at which time most of it was gone, from unknown causes. Similar variability in dominant floral species was noted in pools of other local marshes. One pool under study by Frank and Bleakney (1976; 1978) was devoid of *Ruppia*, whereas an adjacent pool less than 4 m away was invariably choked with *Ruppia* by mid-summer.

Several other marshes in the Wolfville and Canard areas were examined for comparative purposes and specimens collected, but no quantitative analyses were attempted. The Canard marsh 1.6 km south of Pickett's Wharf is unique in the diversity of pools and has yet to be studied. Most of its old dyke wall is extant but has been breached by several large creeks that permit tidal waters to inundate the extensive flat marsh area behind the dyke. There are large shallow pools on the marsh surface, deep pools in the creek channels, and long, narrow excavated pools paralleling both sides of the old dyke wall. In addition, the marsh gradually slopes



Fig 2. Photo of Pool No. 1 looking southeast. Note *Spartina patens* in lower left of picture, *Spartina alterniflora* in lower right, and algae on the pool surface.



Fig 3. Photo of Pool No. 2 looking east. Note floating algal mats and on opposite bank stranded mats swept out of pool by high tides.

away from the base of the dyke and at about 240 m the elevation is 2.6 m lower, and this is the limit of *Spartina alterniflora* which exhibits a very short growth form. This sloping marsh is in contrast to other local marshes which are rather flat and end almost abruptly at the edge of creeks or at wave cut shorelines. There are over 300 pools in the area, situated at every elevation along this slope and the lowest are submerged twice daily by as much as 3 m of water, whereas the upper pools are flushed only during spring tides. These terraced pools often have marshpool species present in abundance at times when we cannot find these same species at pools in nearby 'table-top' marshes. They may, therefore, serve as an important reservoir for marsh species.

Materials and Methods

The vagaries of tide and weather were deemed to be the most severe environmental stresses to which these pools could be subjected. Therefore, in order to document the conditions under which marshpool organisms exist, the flora and fauna were sampled at various extremes in physical factors such as dry periods, just before and after rains, and at certain tidal phases. A total of 27 trips were made to the study area beginning 14 October 1965 and ending 16 January 1967. The number of trips made per month were: October 1965, 3 trips; January 1966, 1; February, 1; March, 2; May, 3; June, 2; July, 7; August, 1; September, 2; October, 1; November, 2; December, 1; and January 1967, 1. During 1965 preliminary examination of the pools took place with a few unmeasured amounts of algae brought into the laboratory from Pool No. 1 for sorting. Beginning January 1966, general observations of marsh conditions, algal growth, conspicuous animals, air and water temperatures, ice thickness, salinities, weather conditions, and other pertinent information were recorded.

Temperatures were taken with a Yellow Springs Model 43 TD or Model 42 SC telethermometer with 3 interchangeable probes for air, water, and surface determinations. Occasionally temperature in the substratum and in algal masses was recorded. From late June to early August maximum-minimum thermometers were placed in the pools at a depth of about 15 cm and read and reset at each visit. Zerbe and Taylor's (1953) density temperature reduction tables were used to determine salinity from the hydrometer and temperature readings taken in the field.

Estimation of the frequency with which the marsh area was flooded involved determining critical heights from comparisons with heights listed in the Canadian Government *Tide and Current Tables* for the mattress at Walton, 30 km away. Reference points were nailed into the wharf pilings at Pickett's Wharf during peak high tides and the height in the tide table noted. On subsequent high tides the process was repeated and the difference between those tides as listed in the tables and actual measurements between the 2 reference points on each post noted. Several such calculations proved that there was little consistency. To the contrary, at times the actual height was 15 cm higher, and at other times 18 cm lower for the same Tide Table height prediction. However, as nearly as could be determined under these circumstances, tides at 6.9 m on the Tide Tables entered Pool No. 1 and tides of about 7.2 m entered Pool No. 2.

From 1966 to 1979 we have witnessed several peculiar (and biologically significant) tidal phenomena in the western Minas Basin. In general the times of high tides agree closely with the official tide tables, but the height can be much higher or lower than anticipated from our considerable past experience with previous similar tide table predictions. This can happen on clear days and does not require strong winds nor extremes in barometric pressure. An apparently unrelated phenomenon is

the unusual duration of high slack tide and low slack tide. A tide usually floods in over the marsh, then stops all movement and within 2 or 3 minutes dramatically reverses its flow, but it may unexpectedly hold the high level mark for as much as 10 minutes. We have observed the same phenomenon during extreme low tides when instead of a quick reversal of flow, the slack water holds its level for periods we have noted in one instance of 20 minutes and in another of 35 minutes. Such unusual extended exposure periods at the sublittoral fringe may account for the death of many adult *Cancer irroratus* in January 1970 (Bleakney 1972).

The first weighed algal samples were taken May 31, 1966, and the last on November 21. Wet algae samples of 0.91 kg (2 lb) were weighed in a fiberglass screen suspended from a spring scale. At each pool samples were taken at three areas (indicated as "a", "b", and "c") to determine whether there was any variation within 1 pool. In the laboratory each sample was sorted and species tabulated.

At first, all the *Hydrobia totteni* were counted but, as the actual numbers per 0.91 kg sample at times exceeded 2000 individuals, densities were calculated from 0.11 kg (0.25 lb) subsamples.

The study pools could not be poisoned; therefore, fish species were obtained with rotenone from other pools on the Canning marsh and on the Canard marsh (1.6 km to the south).

An obvious shortcoming of the algal method of population density determinations was that the algae and fauna were removed from the same site each time depleting that area rather drastically. However, no appreciable local effect was evident over the entire sampling period, and usually no more than 1 or 2 samples were taken per month. Also, as certain spring tides coupled with strong winds were found to sweep out much of the algae on occasion, the damage done by the sampling was minimal. Several times after the algae had been swept out by wind action, some algal-covered *Ruppia maritima* was added to the sample in order to make up a 0.91 kg sample. This created an unfortunate inconsistency in the sampling since not all species common to the algae, *H. totteni*, *L. saxatilis*, *E. chlorotica*, and *A. modesta* for example, were found in the *Ruppia*. However, the *Ruppia* did harbor populations of the bryozoan *Bowerbankia gracilis* and the tube dwelling ciliate *Semifolliculina gigantea*, 2 animals which were considered accidentals by Brough et al. (1960/1961).

Results and Discussion

Physical Factors

1. Salinity: Salinity variation within the pools was determined by 4 factors: tides, rainfall, evaporation, and algal coverage. The diagonal-dash lines in Figures 4 and 5 indicate as nearly as could be estimated from tide tables, periods between which tides did not enter Pools No. 1 and No. 2 during the days between June 23 and August 13. In Pool No. 1 tides did not inundate the pool during the periods 26-27 June (2 days), 5-15 July (10 days), and 25 July to 13 August (20 days). In Pool No. 2 the periods of non flooding were longer: from 23 June to 18 July (24 days) and 24 July to 18 August (25 days).

Water entering the pools in June had a salinity of 29 ‰. The average surface salinity of Pool No. 1 (Fig 4) was 31.4 ‰ with bottom salinities averaging 33.4 ‰. The respective values for Pool No. 2 were 30.2 ‰ surface and 32.4 ‰ bottom.

Rainfall data in Figures 4 and 5 were obtained from the Kentville Research Station, 11 km southwest of the study area. During periods of daily tidal flooding, heavy rains cause a decrease in salinity until the next tide. During periods of non flooding the effects of lowered salinity were prolonged. If there was no wind during

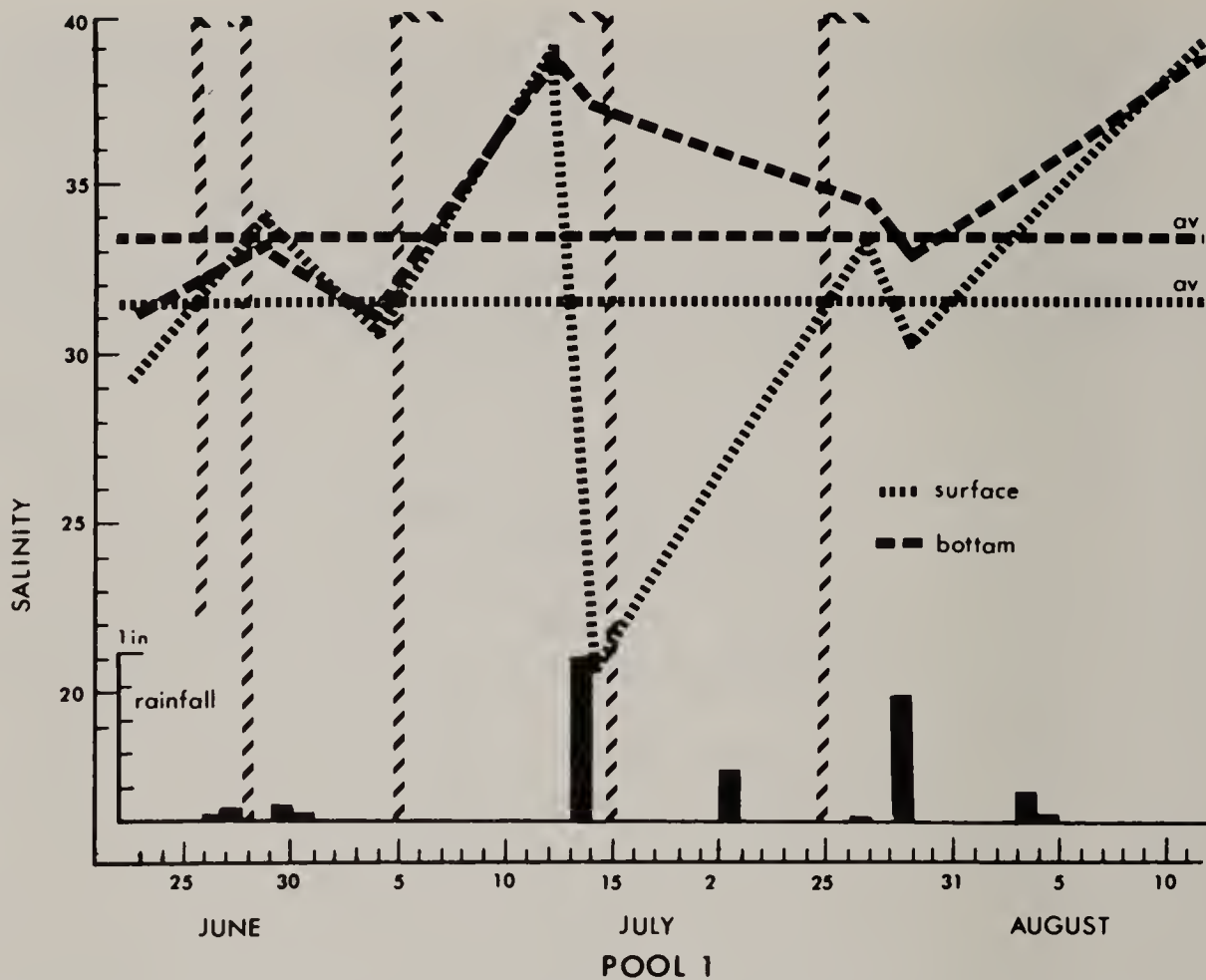


Fig 4. Surface and bottom salinity readings (‰) for Pool No. 1 from 23 June to 11 August 1966. Horizontal lines indicate average salinity. Time periods bracketed by tall vertical broken lines are those when tides did not enter the pool. Solid vertical bars record amount of rainfall reported at Kentville Agricultural Research Station 11 km away.

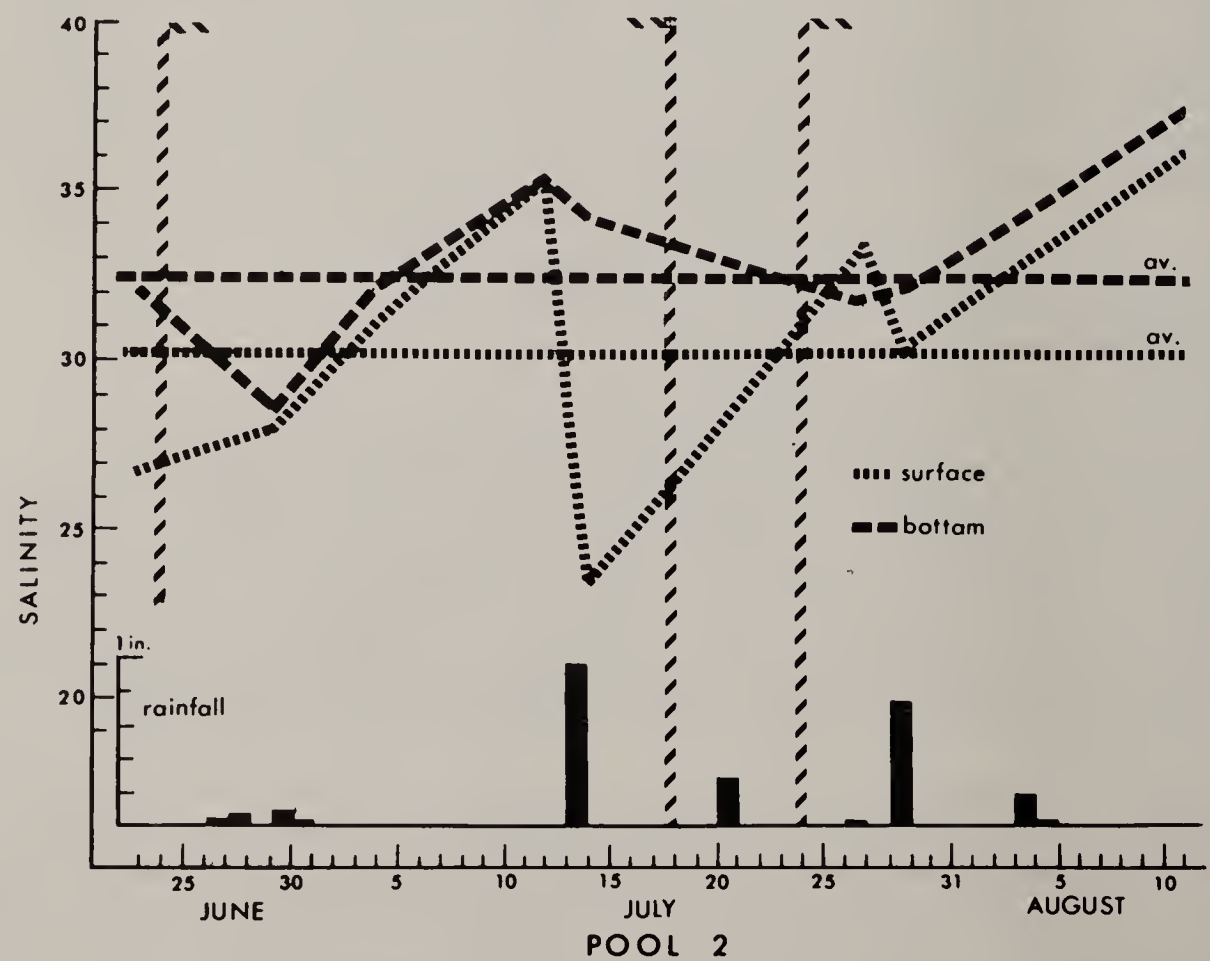


Fig 5. Surface and bottom salinity recordings (‰) for Pool No. 2. Explanation as in Fig 4.

a heavy rain, a stratification of the water took place as illustrated in Figures 4 and 5. The surface and bottom salinities of both pools were nearly the same on 12 July just previous to a day of heavy rainfall. Measurements taken 14 July just after the rain show little change in the bottom salinities (decrease of 1.8 ‰ in Pool No. 1 and 1.1 ‰ in Pool No. 2) but large change in surface salinity (decrease of 13.5 ‰ in Pool No. 1 and 11.3 ‰ in Pool No. 2) as the colder but less dense freshwater remained on top of the warmer, denser saline water. Strong winds soon create a mixing of bottom and surface salinities.

In Pool No. 1 surface salinities rose above bottom salinities on 3 occasions (29 June, 12 July, 11 August) possibly resulting from evaporation. Runoff surface waters after light rains can also increase salinity from first dissolving salt crystals on the substratum and *Spartina* leaves before trickling into the pool. This probably explains the increased salinity of the surface of Pool No. 1 on 29 June.

Pool No. 2, although less exposed to the equilibrating influence of the tide, showed less relative fluctuation in salinity between surface and bottom waters, except after the 2 periods of heavy rain, and also had a lower average salinity than Pool No. 1 (Fig 4). This may have resulted from extensive algal coverage which would have reduced evaporation keeping surface salinities lower than the bottom salinity thereby lowering average salinity in the pool. The higher surface salinity of 27 July may have resulted from the wind blowing the algae to one end of the pool exposing a larger surface area to evaporation.

The range of salinity for Pool No. 1 was from 20.5 ‰ to 39.3 ‰ surface and from 28.2 ‰ to 38.9 ‰ bottom. For Pool No. 2 the range was surface 32.5 ‰ to 36.3 ‰ and bottom 28.5 ‰ to 37.2 ‰. Thus the average salinities of these pools were quite unlike the average low salinities reported by Nicols (1935) in Scotland. She divided pools into 2 groups, those having a low average salinity of less than 5 ‰, and those having an average salinity of 15 to 20 ‰. During hot weather salinities rose as high as 40 ‰ and in wet weather dropped as low as 8 ‰. Naylor and Slinn (1958) studied the flora and fauna of pools at Scarlett Point, Isle of Mann. Only 6 visits were made over a period of 3 years, however. The highest salinity recorded was 38.6 ‰ while the lowest of 1.0 ‰ to 4.1 ‰ were recorded just after a rain. Table 1 summarizes miscellaneous salinity and temperature data from Minas Basin marsh pools, 1966 to 1977. These pools are, on an average, hypersaline to the waters in the immediate Minas Basin. Thus, in summer, they constitute a warm lentic environment of near oceanic salinities. The lowest salinities recorded, just over 11 ‰, were surface readings and 1 of these followed a 10 day period of rainy weather (Table 1).

II. Temperature. The shallowness of the pools result in temperatures warmer during the day than the air temperatures. Bottom temperatures tended to be lower than surface temperatures except in the case of Pool No. 1 after the rain of 13 July (Fig 6). The solar radiation on 14 July, although insufficient to significantly warm the surface water of Pool No. 1, was sufficient to raise the algal mats (through oxygen production) from the bottom of Pool No. 2 thus warming the surface through greater heat absorption by the algae (Fig 7).

During winter the pools may be covered by ice by varying thickness. On 5 December 1965, 15 January, and 24 February 1966, the ice on Pool No. 1 was 5 cm, 24 cm, and 14.5 cm thick respectively, whereas Pool No. 2 was covered with 1.3 cm, 10 cm, and 20 cm of ice on the same dates. Why should two adjacent pools in the same habitat show an inverse relationship in thickness of ice cover and by factors as large as 2 and 4? On 24 February, large blocks of drift ice were noted scattered over

Table I. Miscellaneous temperature, ice, and salinity measurements at salt marsh pools, Kings County, Minas Basin, 1966-1977. Norenburg's work included small shallow pools not considered by the other authors.

Data Source	Dates	Temperature Range °C	Ice Thickness cm	Salinity (‰) Bottom	Surface
BAILEY (1967)	Jan-Nov 1966 June-Nov 1966 12 Jan 1967	-1.5 to 28.5	50	28.5-38.9	20.5-39.3
BLEAKNEY (unpubl)	25 Jan 1970 27 Jan 1971		30 46-50		
FRANK (1974)	9 Jan-15 Nov 1973	-1.0 to 26	19	22.6-39.3	11.9 (10 days rain)
NORENBURG (1976)	Sept 1974 to Feb 1976	-1.5 to 28	30	19.7-31.9	11.1-23
BLEAKNEY (unpubl)	8 March 1977		68.5		

Table II. Dominant animal forms found in pools of the *Spartina* marshes in Kings Co., N.S. 1965-67. Species marked with asterisk were often abundant.

PROTOZOA		ARTHROPODA	
Ciliata:	<i>Semifolliculina gigantea</i> Dons	Acarina:	Red Mites
CNIDARIA		Crustacea:	* <i>Gammarus mucronatus</i> Say <i>Orchestia grillus</i> Bosc
Actinaria:	* <i>Nematostella vectensis</i> Stephenson	Insecta:	<i>Enochrus hamiltoni</i> Horn * <i>Ephydra riparia</i> Fallen <i>Tabanus nigrovittatus</i> Macq. *Corixids
NEMERTEA:	* <i>Lineus viridis</i> (Fabricius) <i>Prostomatella obscura</i> (Schultze)		
MOLLUSCA		ECTOPROCTA	<i>Bowerbankia gracilis</i> Leidy
Gastropoda:	* <i>Hydobia totteni</i> Morrison * <i>Littorina saxatilis</i> (Olivi) <i>Littorina littorea</i> (Linné) <i>Ilyanassa obsoleta</i> (Say) <i>Alderia modesta</i> (Lovén) * <i>Elysia chlorotica</i> (Gould)	CHORDATA	
Pelecypoda:	<i>Geukensia demissa</i> (Dillwyn) <i>Gemma gemma</i> (Totten)	Pisces:	<i>Anquilla rostrata</i> (Le Sueur) * <i>Fundulus heteroclitus</i> (L.) <i>Gasterosteus aculeatus</i> L. <i>Apeltes quadracus</i> (Mitchill) <i>Pungitius pungitius</i> (L.)

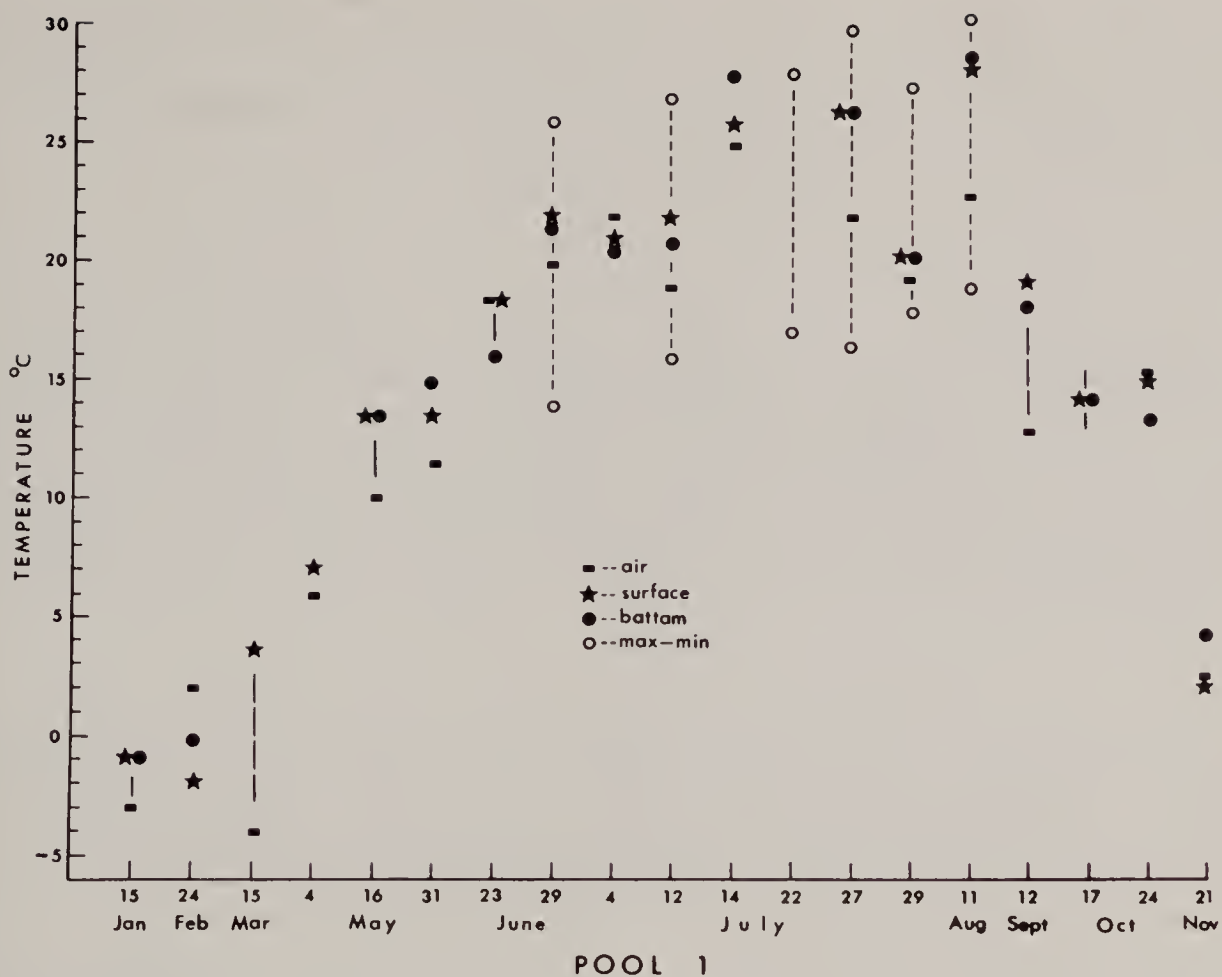


Fig 6. Temperature fluctuations recorded at Pool No. 1. Air temperatures taken near 1.5 m above ground. Pool temperatures taken within 2 cm below surface, and within 2 cm above bottom. Each maximum and minimum range recorded (late June to early August) covers entire period from previous visit and at water depth of 10-20 cm.

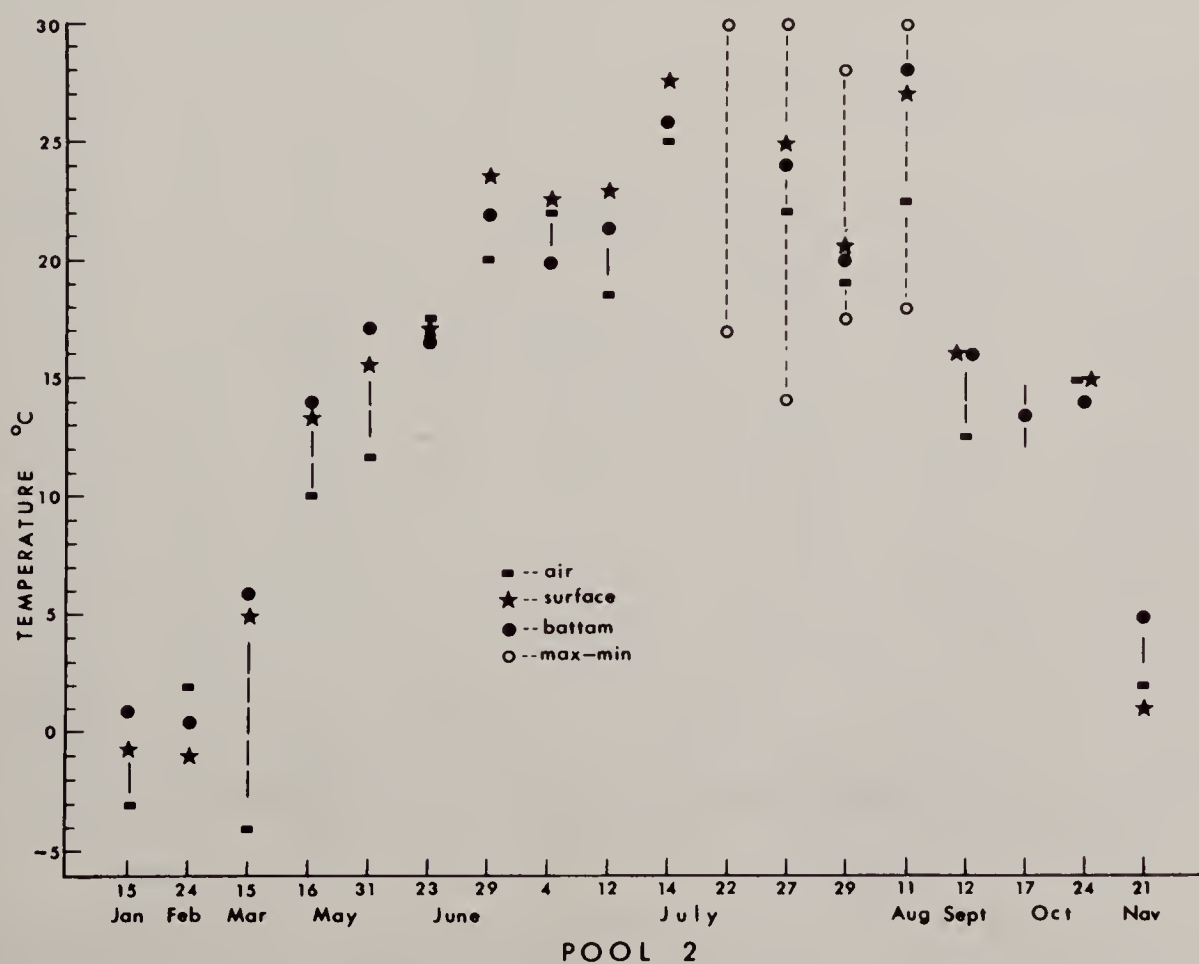


Fig 7. Temperature fluctuations recorded at Pool No. 2. Explanation as in Fig 6.

the marsh. Observations on 16 January 1967 revealed the phenomenon of 'ground ice'. Pool No. 2 had 18 cm of hard ice, 32 cm of slushy ice, and a thin ice layer of 1.3 to 2.5 cm lining the bottom. Pool No. 1 was in a similar condition with a total of 50 cm of ice and slushy ice from mud bottom to snow cover.

Maximum and minimum temperature variations during any one time period between pool visits are indicated in Figures 6 and 7 and are summarized in Table I with additional data from 1970-77. The low temperatures of February 1977 froze shallow marsh pools to the bottom, but the deepest pool on Kingsport marsh had 18 cm of water beneath 68.5 cm of ice. Measurements were taken of this ice cover until it disappeared on 3 April. Figure 8 shows that the pool water depth remained stable and that the ice block remained fixed, but by 28 March the ice had lost 29 cm from its upper surface and only 4 cm from its submerged surface. Yet 5 days later, this very persistent massive ice cover was reduced to a floating block 4 cm thick and the following day it was gone.

Fauna

Harsh though the conditions seem, many organisms inhabit these pools summer and winter. Gastropods were the dominant inhabitants represented by 6 species. There were 2 pelecypods; the ribbed mussel, *Geukensia demissa*, a common inhabitant of the Tantramar saltmarshes of New Brunswick, but certainly rare in Minas Basin marshes, and *Gemma gemma*. The latter species was common in the marsh pools of Canard but was not found at the Canning study pools 1.6 km to the north. Several insect species frequent these pools and their larvae as well as the abundant amphipods were prey for 5 species of fish. A semi-sessile anemone, *Nematostella vectensis*, the sessile bryozoan *Bowerbankia gracilis*, and the large tube-dwelling protozoan *Semifolliculina gigantea* were common. A list of the fauna compiled from 1965 to 1967 field studies is presented in Table II. Several of these species received special attention, and pertinent observations and updated comments are presented here.

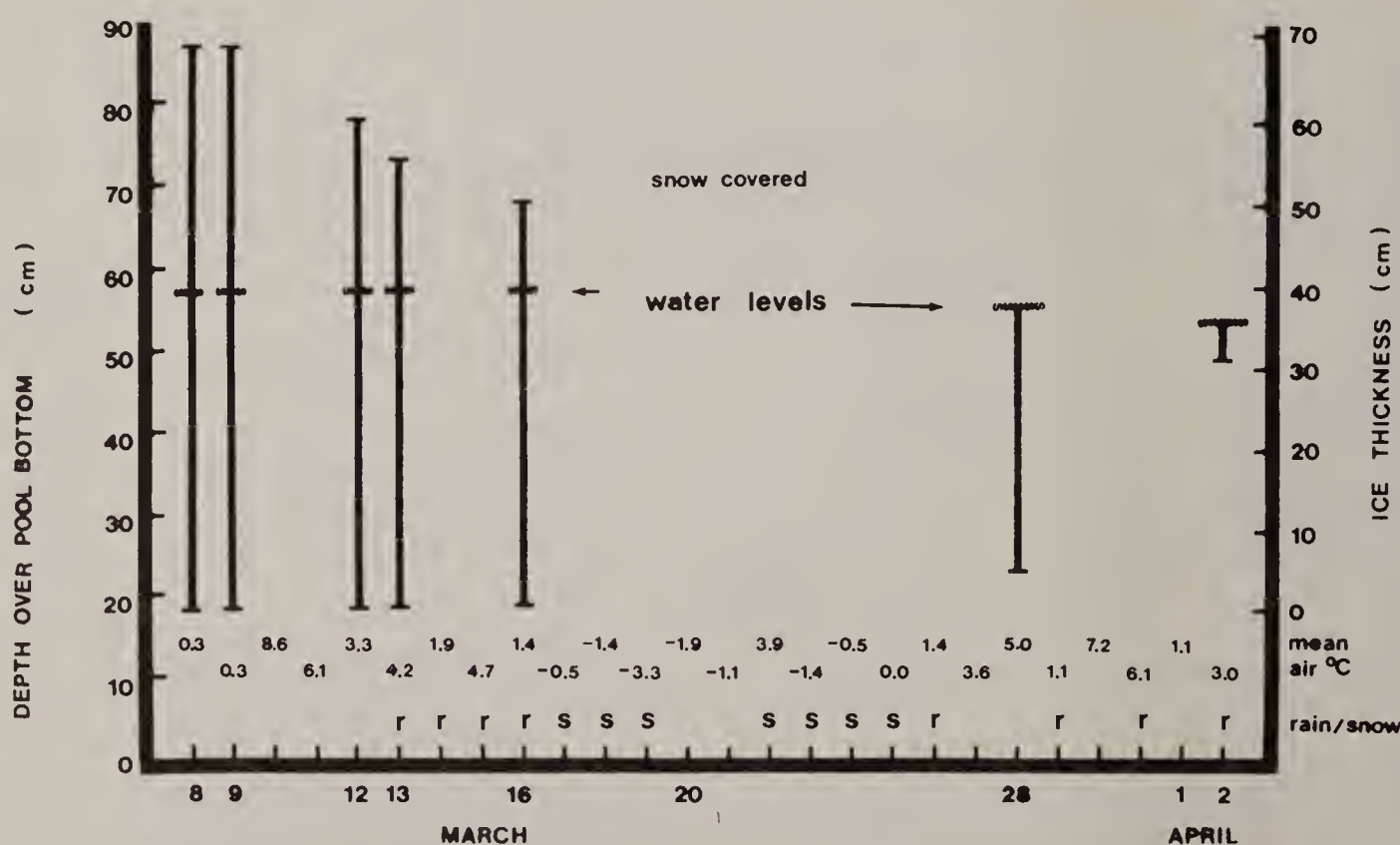


Fig 8. Ice melt sequence in a 12 x 5 m pool on Kingsport marsh March 8 to April 2, 1977. From beneath the 68.5 cm of ice on March 8, a pool bottom sample contained green filamentous algae and new green shoots of *Spartina alterniflora*.

Phylum Protozoa

Semifolliculina gigantea: This large tube-swelling ciliate was found on the stalks of *Ruppia maritima*. The colonies were intermingled with those of *Bowerbankia gracilis*.

Phylum Nemertea

During the summer of 1966, all the algal samples contained an abundance of green nemertines. During autumn, this handy source was used routinely in laboratories for live demonstration but by 1970 they had disappeared from these same marsh pools. Collections preserved in 1966 were identified by Jon Norenburg (Northeastern University, Marine Science Institute, Nahant, Mass., in litt. 1979) so we know that most were *Lineus viridis*, but 2 specimens of *Prostometella obscura* were also present. In January and October of 1970 only *P. obscura* were extracted from the algal samples employing the same technique of allowing the algae to stand in open trays at room temperature for several days until all the animals had surfaced. When Norenburg surveyed these same pools specifically for nemerteans during 1974 to 1976, he found both species but *L. viridis* was rare and, although difficult to locate, *P. obscura* was common enough to risk a thesis commitment (Norenburg 1976).

Phylum Cnidaria

Nematostella vectensis: This small anemone was first observed on 14 October 1965. Subsequent sampling always revealed this cnidarian, even beneath ice on 15 January 1966. It commonly occurred imbedded in bottom ooze with only its tentacular whorl exposed, or stretched out on the substratum, or entwined in floating algae (Bailey & Bleakney, 1966). Specimens collected June, July and August 1966 were larger than those taken at other seasons and far exceeded the largest (15 mm) reported by Hand (1957) from California. Measurements of relaxed specimens ranged from 1 to 60 mm, averaging 25 mm. However, of 518 specimens measured in 1973 by Frank (1974) the largest was only 47.4 mm.

The variations we have noted over the past decade relative to distribution and population density will have to be taken into consideration by workers conducting short-term environmental impact studies. For example, in 1972 the 1966 study pools at Pickett's Wharf were devoid of *Nematostella*, so a new study site was established (October 1972 - January 1974) on the Kingsport marsh (Frank 1974). One particular pool, in a close group of 4, invariably had *Nematostella* present, summer and winter, even beneath heavy ice cover. On 1 occasion (12 October 1973) 181 *Nematostella* were extracted from a single 15 cm x 15 cm x 2 cm sample of pool bottom silt. However, in the summer of 1975 there was none in this pool, but an adjacent pool, which produced but a single specimen in 1973 samples, was now the major site for *Nematostella*. Previous to 1975 the average density per sample was near 45 specimens (max. 181) and the greatest densities were always in September or October and the least in June and July. This "established pattern" in our minds was dramatically shattered when on 9 July 1975, in a small Wolfville marshpool, the count from a 15 cm² sample (ca. 225 cm³) was an unprecedented 1,816 *Nematostella*.

Phylum Mollusca

Hydrobia totteni: This small gastropod was always present in large numbers in the algae and on the bottom of the pools. Figure 9 records adult population fluctuations

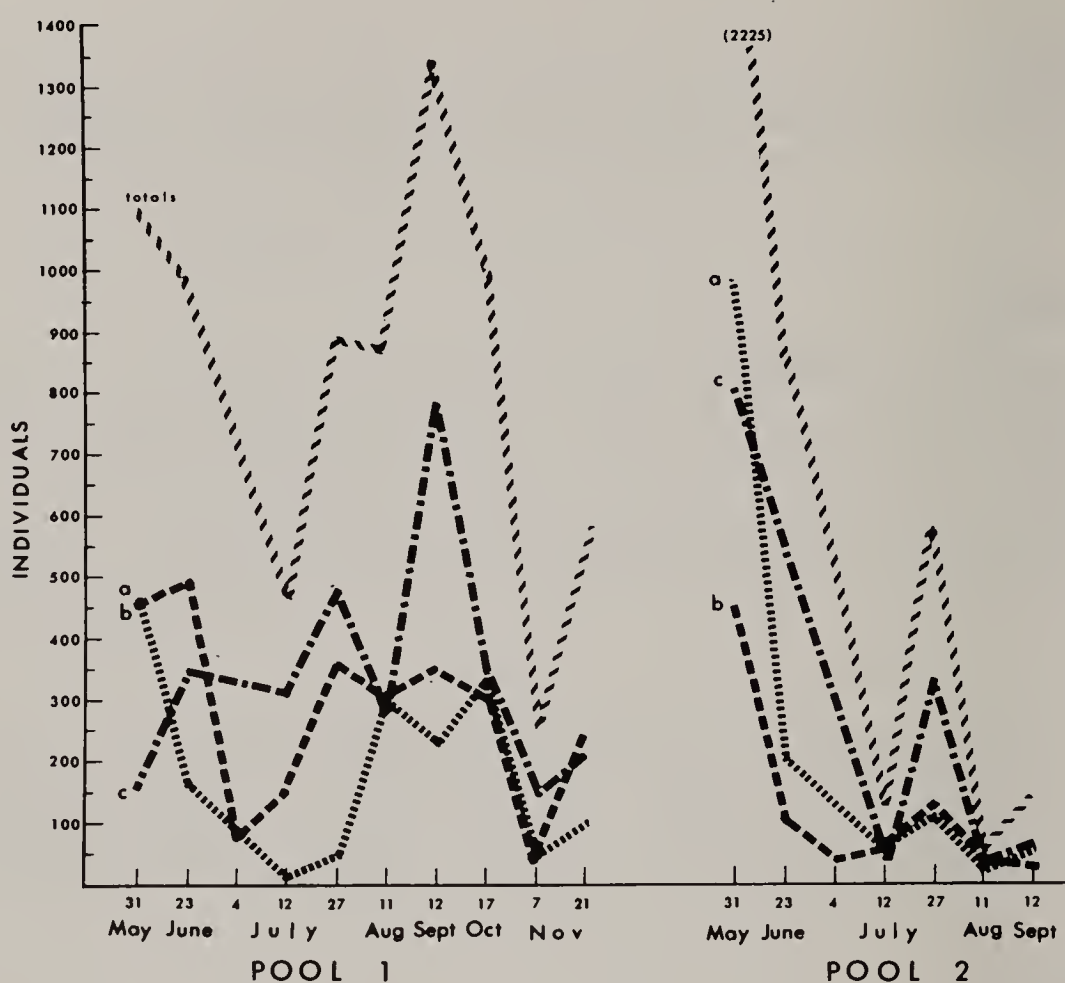


Fig 9. Population density fluctuations of *Hydrobia totteni* in areas "a", "b", and "c" of Pool No. 1 and Pool No. 2 based on 0.11 kg (0.25 lb.) algal samples. Upper line represents number of individuals in combined samples.

in 1966 between 31 May and 21 November (12 September in the case of Pool No. 2) per 0.11 kg (0.25 lb) algal samples. Numbers of adults varied from as few as 7 individuals on 12 July (area "a" of Pool No. 1) to about 1000 individuals on 31 May (area "a" of Pool No. 2). However, when the number of individuals was low in one area, it could be high in an adjacent area.

Littorina saxatilis: The Northern Rough Periwinkle was relatively common in the algae. Numbers of individuals varied from 4 shells in area "c" of Pool No. 1 to 235 shells in area "a" of the same pool on October 17 per 0.91 kg (2 lb) sample of algae (Fig 10). Numerous young appeared between 12 July and 11 August and the adults in "c" and "b" of pool No. 1 tended to decrease in number.

Littorina littorea: Although common on rocks of the intertidal region and on the nearby wharf pilings, the Common Periwinkle was rarely found in the pools. When present, individuals varied in size from small to medium. In contrast, this species occurred regularly in the Canard pools on *Ectocarpus* sp. (an alga absent from the Canard pools) and attained much larger size.

Ilyanassa obsoleta: The detritus rich mud around the lower reaches of the *Spartina alterniflora* zone and the mud below that region was densely carpeted by the Mud Snail, but in the study pools it occurred sparsely. Eggs were found attached to *Ruppia* stalks on 31 May. However, in some of the lower terraced pools of the Canard area it was found in densities of up to 537/m².

Alderia modesta and *Elysia chlorotica*: These 2 sacoglossan gastropods were of

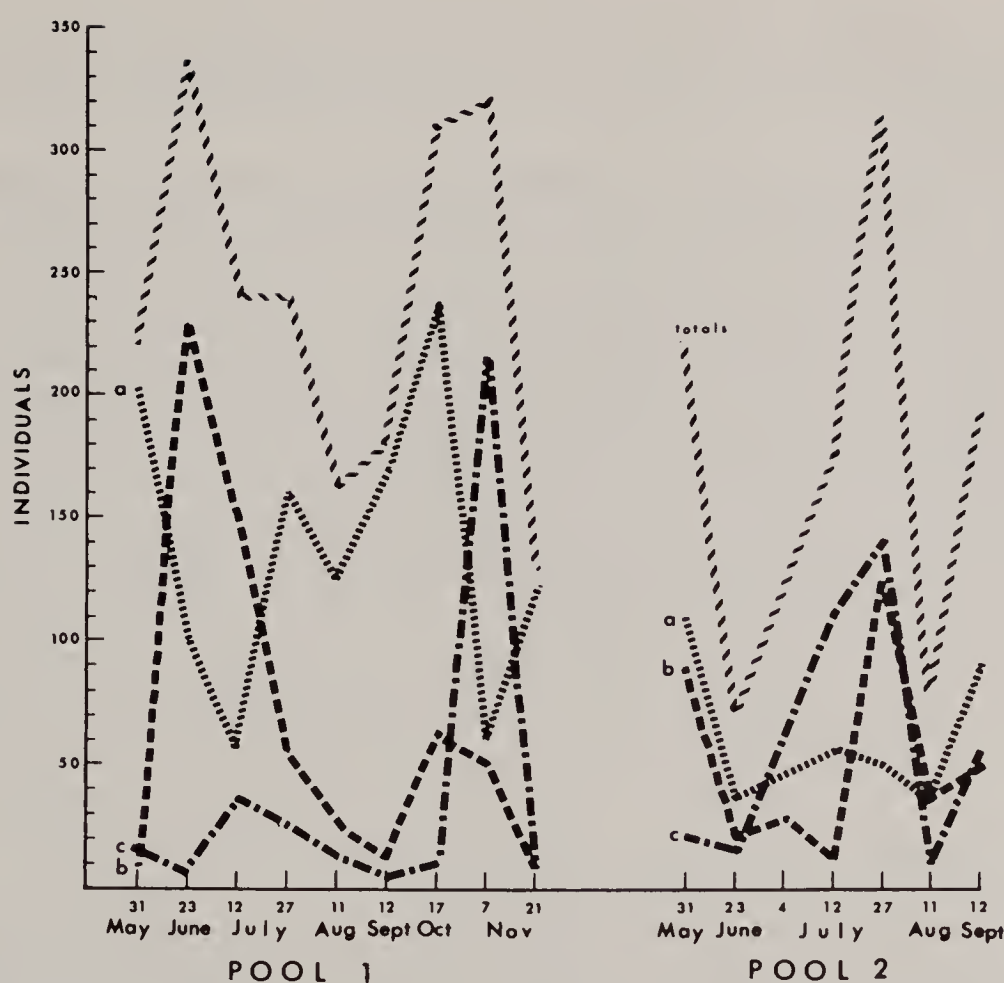


Fig 10. Population density fluctuations of *Littorina saxatilis* in areas "a", "b", and "c" of Pool No. 1 and Pool No. 2 based on 0.91 kg (2 lb.) algal samples. Upper line represents number of individuals in combined samples.

special interest since very little was known of their life histories and ecology. In addition, this was the first *E. chlorotica* record for Canada and the second Canadian report of *A. modesta*, the other being Grand Manan Island (Bailey & Bleakney 1967; Bleakney & Bailey 1967).

Recent studies by Graves et al. (1979) have established that *E. chlorotica* and *A. modesta* both consume *Vaucheria*, but that *E. chlorotica* incorporates the *Vaucheria* chloroplasts as functional photosynthetic units within its digestive tract cells.

Alderia were also present at Canard extending into the upper marsh where *Spartina patens* predominates and above the reach of all but the highest tides. Sixteen specimens 4 mm to 8 mm were collected 5 August 1966, from one area on the Canard Marsh. They were found in grass tunnels amongst the feces of the meadow mouse, *Microtus pennsylvanicus*, adjacent to an orchard. The abundant insects and mouse tunnels of the upper marsh provide an unusual contrast to the winter-pool habitat of this "marine" organism. On the high marsh this slug must withstand the abrupt salinity changes of tides and rain as well as potential desiccation by sun and wind. On the Wolfville marsh 1 recorded temperature taken on a sunny day with a tele-thermometer disc on an *A. modesta* 'basking' on a *Vaucheria* mat cushion was 25.5° C.

The size of specimens from algal samples in 1966 range between 2 and 15.5 mm, the latter figure being much larger than the maximum of 8 mm reported by Hand and Steinberg (1955) and Abbott (1975). It is interesting that no specimens greater than 8 mm were ever found on the *Vaucheria* outside the pools.

The largest *A. modesta* and *E. chlorotica* have been found only in the pools. The puzzling aspect was their sudden appearance in the pools in autumn and their sudden disappearance from the pools in spring. Large 15 mm *A. modesta* were not col-

lected again until the winter of 1969-70 when they were unusually common in some pools. Not until the winter of 1975-76 were large ones observed again, and these were 12 mm not 15 mm.

Elysia chlorotica: This large emerald-green sacoglossan was first noticed in Pool No. 1, 14 October 1965, when 4 were observed and collected. Since then it has been observed at most of the local marshes. On the same day it can be found on *Vaucheria* cushions, on mud at the base of *Spartina alterniflora*, on the overhanging sides of creeks, submerged in pools along the drainage creeks, and in pools on the high marsh. At Pool No. 1, on 16 January 1967, live specimens were found in pockets on the underside of 18 cm of ice cover. The greatest density to date was recorded (and photographed) at Pool No. 1, 24 October 1966, when 75 m² were on the submerged algal mats. The largest individuals in any year occurred in the pools and were in the 26 to 46 mm size range which certainly exceeds Abbott's (1974) limits of 20 to 30 mm. However, specimens observed on the open marsh were rarely over 12 mm in length. The extremely large individuals were common on 9 December 1969 and 23 November 1970 at Kingsport marsh pools, but in 1972 and 1973 there were none although 3 km to the south in the Canard pools they were common on 22 October 1972. At Pickett's Wharf the dense populations of 1966 were gone by 1970 and specimens were not seen there again until 30 November 1976; further demonstration of natural fluctuations in marsh pool populations.

Stiliger fuscata: This sacoglossan is relatively small, 6 to 8 mm, but its black color renders it most conspicuous on green algae and on the brown substrate of the pools. We can say with assurance that it was not in the marshes of the western Minas Basin in 1966. On 21 October 1970, a single specimen was observed, collected, and photographed. Not until September 1972, was another found in spite of our diligent efforts in the interim. This 'rare' species suddenly increased in 1973 and 1974 to such densities that a small sample of pool algae, enough to half fill a 16 oz jar, would produce over 120 *S. fuscata*. The population declined in 1975 and by autumn of 1977 we considered them rare.

Gemma gemma: In July and August 1966 this small pelecypod was found in numbers as high as 50 to 96 per 0.91 kg algal sample from the Canard marshes, but was never found in the Canning pools.

Phylum Arthropoda

Gammarus mucronatus: Reported as a "warm water endemic" by Bousfield and Leim (1960), this amphipod was present in great numbers throughout the sampling period, reaching a peak in July and August at which time young were present. On 9 November 1966 the count from a 0.91 kg algal sample was 122 specimens. They were found active even beneath the ice, although on 24 February 1966, winter kill of both algae and animals was observed in Pool No. 2.

Bousfield (1956; 1973) reported this species occurring in Nova Scotia in salinities ranging from 4 ‰ to 28.7 ‰. The highest salinities of our study pools, 39.3 ‰, indicate that this species can live at salinities much above those previously recorded.

Orchestia grillus: This second "warm water" amphipod was most often found in the moist *Vaucheria* mats and was observed only once in the pools, at a time when a high tide was just receding from the marsh. On 12 July 1966 many live individuals were found in folds of algal mats swept out of the pools by the June high tides. Bousfield (1956) reported habitat salinities ranging from 18.0 ‰ to 28.7 ‰.

Enochrus hamiltoni: Throughout the period from May to August this water beetle occurred regularly in the samples.

Ephydra riparia: Larvae and pupae of these shore flies were abundant throughout the summer but disappeared by September.

Tabanus nigrovittus: Only 1 larva was found.

Corixidae: Water boatmen were first observed 27 July 1966, at which time they occurred in great numbers in algal samples of both pools. High numbers of 15 to 68 individuals per 0.91 kg algal sample, which persisted through August, gradually decreased to only 2 specimens in November. In 1973, instars were common in benthic samples in spring and early summer and progressively increased in size. Adults of summer were derived from this overwintered population of eggs or instars.

Acarina: Red mites were common from May to August disappearing completely from the algal samples by September.

Phylum Chordata

Fundulus heteroclitus: Killifish were seen throughout the summer in both study pools. Eggs and young were taken in algal samples and young persisted through to 20 September. On the Canard marsh, *F. heteroclitus* was seen as late as 9 November. During 1 particular high tide in 1966 when the *Spartina* near Pickett's Wharf was flooded to a depth of about 0.45 m, schools of this fish were observed leaving the pools and feeding actively as they worked their way through this submerged 'hay field'. In some instances they appeared to let the flood of the tide carry them along. Whether these groups of foraging fish return to their home pools was not determined, but the absence of stranded fish on the marsh and the presence of the usual complement of killifish in the pools after the tide had receded would indicate the probability of homing behavior. From observations at the Kingsport marsh in 1973, there were two categories of killifish foraging patterns in the *Spartina* during extreme highwater spring tides. As tidal waters flooded over the marsh from the creeks, discrete schools of *Fundulus* come in with this flood and these feeding units were particularly conspicuous on dead-calm days. When the rising waters finally reach the upper marsh pools, the resident killifish were observed to school away into the *Spartina* where they become indistinguishable from the groups already there. There was, then, a sporadic but intense utilization of invertebrates of the marsh vegetation (insects, spiders, mites) by fish resident in the pools and by schools from the Basin proper.

Gasterosteus aculeatus, *Gasterosteus wheatlandi*, *Apeltes quadricus*, and *Pungitius pungitius*: All 4 species of sticklebacks were collected from poisoned Canard terraced pools on 28 June 1966, but on 9 November only *P. pungitius* was present. Rotenone treatment of a marsh pool (8.3 x 1.5 x 0.5 m) on the Kingsport marsh on 26 August 1975 produced 379 fish specimens: 335 *F. heteroclitus* (52 gm), 38 *Anguilla rostrata* (262 gm) and 6 *Apeltes quadricus* (1.4 gm). Two of the larger eels (length 32 and 33 cm) emerged and fled across the marsh surface.

Anquilla rostrata: The American eel was never seen in the Canning pools but on 14 July 1966, the shallow gully draining that part of the marsh was poisoned (rotenone), and eels quickly emerged from the bottom silt and escaped downstream.

Conclusions

The uniform appearance of Minas Basin *Spartina* marshes could easily lead to the assumption that pools in such a monotonous habitat would be equally uniform. The evidence from this study is to the contrary for even 2 adjacent pools showed variations in species composition, population densities, and physical factors. Although just 30 m distant, Pool No. 1 showed algal characteristics different from Pool No. 2. Population densities of areas "a", "b", and "c" of Pool No. 2 showed more coincidence in fluctuations than did those in Pool No. 1. Average salinities were higher in Pool No. 1. *Alderia modesta* and *Elysia chlorotica* were more abundant in Pool No. 1. *Gemma gemma* of the nearby Canard Marsh were altogether absent from the Canning marshes. Further, within 1 pool, areas only 3 m apart were distinct from month to month. Bromley's 1976 to 1978 survey of 5 Minas Basin estuarine marshes adds further evidence of surprising faunal diversity between contiguous similar marshes (Bromley 1978).

Over this 12-year period (1965-1977), significant natural fluctuations in densities, local distribution, and even average sizes were observed for 3 species of sacoglossans, an anemone, and two nemerteans.

The diversity and instability of environmental parameters are an essential characteristic of these marsh pools. When tides do not enter the pools for 20 days or more, there may be periods of cool, rainy weather or a persistent summer heat wave. Also, at such a time, the diurnal periodicity of day-night temperature changes may be strongly felt. However, then the tides are flooding these pools twice daily, but at different times, such diurnal patterns would be robbed of their periodicity. As the precise height and action of these spring tides are unpredictably affected by wind and/or barometric pressure and as there is no regular seasonal pattern in flooding sequence of the marsh pools (Bleakney 1972), then tidal cycles are of little consequence in establishing rhythms to which marsh pool animals could adapt and synchronize any intrinsic biorhythms.

Acknowledgement

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COMPARISON OF CARBON CONTENT OF THE SEDIMENTS AND THEIR PORE WATERS IN SALT MARSHES AT KINGSPORT AND GRAND PRÉ, MINAS BASIN, BAY OF FUNDY, NOVA SCOTIA *

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In the salt marshes along the Bay of Fundy, Nova Scotia, large standing crops of plant biomass are developed during the spring and summer when relatively high levels of primary production are maintained. The effect of this fixed carbon (both particulate and dissolved) on the open Bay of Fundy is difficult to determine. In this study, the organic carbon in the sediment and in the interstitial or pore waters were measured using methods which are described. There were large differences in measured organic matter between the 2 physically different marshes studied. Although the influence of such areas on production in the Bay of Fundy cannot be estimated from this preliminary study, the high organic levels observed indicate that marsh areas may be a source of organic matter.

Introduction

Production in the Bay of Fundy may be enhanced by organic matter from salt marshes in this region. During spring and summer, the primary production of these marshes is relatively high and large standing crops of plant biomass develop (Smith 1978). Because of the large tidal range in the Bay of Fundy, export from the marshes of fixed carbon (living and detrital) with drainage during the ebbing tide is expected (Odum & de la Cruz 1967; Shisler & Jobbins 1977). The study of the flux of particulate organic matter from marshes has been examined (Valiela et al. 1978). However the flux of dissolved organic carbon from marsh areas is not well understood (Woodwell et al. 1971; Shisler & Jobbins 1977). In marsh environments, with high levels of productivity, with excretion from plants (Wetzel & Renhale 1979), and with high microbial activity, high levels of organic matter will be found in the sediments which may be a major source of dissolved organic matter (Pomeroy et al. 1976). The pore or interstitial waters of sediments are rich in dissolved organic matter (Martens & Goldhaber 1978) which can be added to overlying waters by diffusion from or resuspension of the sediments.

In this study, the sediments in 2 marshes were examined. The organic carbon and water content of sediments along specific transects were measured during the summer of 1978. The dissolved organic content of the pore waters was measured by a simple technique allowing rapid analysis of small sediment samples with water contents in the range 25 to 60%. The results obtained from these marshes showed differences which will be discussed.

Materials and Methods

Samples were collected at low tide along transects on marshes near Kingsport and Grand Pré on the Minas Basin of the Bay of Fundy, Nova Scotia. Fine grained

sediments of clay-silt nature were found in both marshes (Smith 1978). The marsh at Kingsport is older with well-developed drainage channels and with relatively high diversity of angiosperm species; the Grand Pré marsh is younger, in the early stages of physical development and with low species diversity (Smith 1978). Surface sediment samples (0.5-1.0 cm depth) were collected with a stainless steel spatula. After digging a small hole, subsurface sediments were sampled with the spatula (8-10 cm depth). Samples were stored frozen (-20°) in precleaned (400° for 4 h) glass bottles sealed with caps lined with aluminum foil.

The water content (%) of the sediment was determined gravimetrically by drying aliquots (20-30 g) of the sediment at 100 to 110° .

The organic carbon content (% of dry sediment) of the sediment was determined by high-temperature oxidation (900°) of aliquots of sediment which had been homogenized after drying. The inorganic carbon was either removed by acid treatment (HCl) or measured to allow for correction of the calculated organic carbon contents. Dried sediment samples (1-3 mg) were weighed into quartz tubes (25 mm x 4 mm ID). The organic matter was oxidized to CO_2 and measured with a non-dispersive infrared analyzer (MacKinnon 1978).

The dissolved organic carbon concentration in the sediment pore waters was determined by a high-temperature oxidation method. The separation of pore waters by a centrifugation procedure was found to be unsatisfactory because of the low water content and clay-silt nature of the sediments. Therefore, a simple squeezing procedure was developed, by which water from small sediment samples was extracted quickly and then analyzed for the organic content. A portion of thawed sediment was transferred to the bottom half of a petri dish, cleaned (400°) of organic matter. A cleaned (400°) glass fiber filter (47 mm, Whatman GF/C) was placed on the sample so that water in the sediment was absorbed. Then smaller segments of pre-weighed (10-20 mg) glass filters (cleaned at 400°C) were patted on the wetted larger filter to absorb pore waters without contamination from the sediment or any suspended particles. This filter segment with its absorbed water was quickly weighed to determine the volume of water absorbed ($75\text{-}100\mu\text{ l}$). The filter was placed in a quartz tube (25 mm x 5 mm ID), acidified with H_3PO_4 , and dried in an atmosphere free of organic matter (MacKinnon 1978). After drying, the quartz container with sample was introduced into a high-temperature oxidation furnace and the organic matter was measured as CO_2 . The DOC concentrations are expressed as mg C l^{-1} or ppm C. When this method was tested with standard dextrose solutions, high efficiency of recoveries was obtained (Table I). Standards were prepared by slurrying dried, homogenized organic-free sediment (600°) with dextrose solutions (50-500 ppm C) to yield muds of various water contents (40-65%). The extraction method described above proved useful for measuring the DOC concentrations in the pore waters of clay-silt marsh sediments with high organic carbon concentrations and of variable water content (24-55%).

The concentration of the dissolved inorganic carbon (DIC—includes carbonates and dissolved CO_2) was determined using the method described above to extract pore water. After absorbing a measured amount ($100\text{-}200\mu\text{ l}$) of pore water, the glass-fiber filter was added to a phosphoric acid solution (10%). The CO_2 purged from the solution was measured with an infrared analyser. The inorganic carbonate concentration is expressed in mmolar (mM) units.

Results

The results of analyses of samples from the study areas for water content, organic carbon content of the sediments, and for the dissolved organic and inorganic carbon

Table I.Evaluation of method used for extraction and measurement of DOC concentration in pore waters

A. Effect of varying DOC concentration of pore water

Calculated* DOC concentration (ppm C)	Measured DOC concentration (ppm C)	% Recovery
50.5	63.3 + 1.4	125
106.4	126.4 + 0.9	119
240.0	280.7 + 0.8	117
511.8	546.0 + 16	107

Mean % Recovery = 117 + 7

B. Effect of % water content on efficiency of recovery

Water content of mud** (%)	Calculated DOC concentration (ppm C)	Measured DOC concentration (ppm C)	% Recovery
40	106.4	129.7 + 1.5	122
50	106.4	126.4 + 0.9	119
57	106.4	121.9 + 8.9	115
63	106.4	121.9 + 8.9	115

Mean % Recovery 118 + 3

*50% Slurry of organic-free sediment plus various concentrations of dextrose solutions.

**Various amounts of dextrose standard solution (106.4 ppm C) added to organic-free sediment to yield mud.

concentration in the pore waters are shown in Figures 1 and 2. During the period of this study, there was little change in the various parameters measured in either marsh, even though plant biomass increased considerably during the summer months (Smith 1978). In both marshes, organic carbon and water contents of the sediment, and concentrations of dissolved organic carbon in the pore waters were generally higher in surface than in subsurface sediments. However, higher concentrations of dissolved inorganic carbon were found in the reducing zone of the subsurface sediments where there was probably a high level of microbial activity. Differences were observed in the parameters measured on the 2 marshes (Table II). The organic carbon content of both the sediment and the pore waters (surface and subsurface zones) of the older marsh at Kingsport were higher than those measured on the marsh at Grand Pré. As well as higher concentrations, a higher variability (standard deviations, Table II) in both the surface and subsurface zones was observed on the Kingsport marsh. On the Kingsport marsh, higher plant diversity was observed yet a similar level of above ground biomass production was measured on both marshes (Smith 1978). The high variability of parameters measured on the Kingsport marsh indicate this marsh is more heterogeneous than the Grand Pré marsh, where a more homogeneous distribution of the biota was observed and the measured parameters, that we report, were less variable.

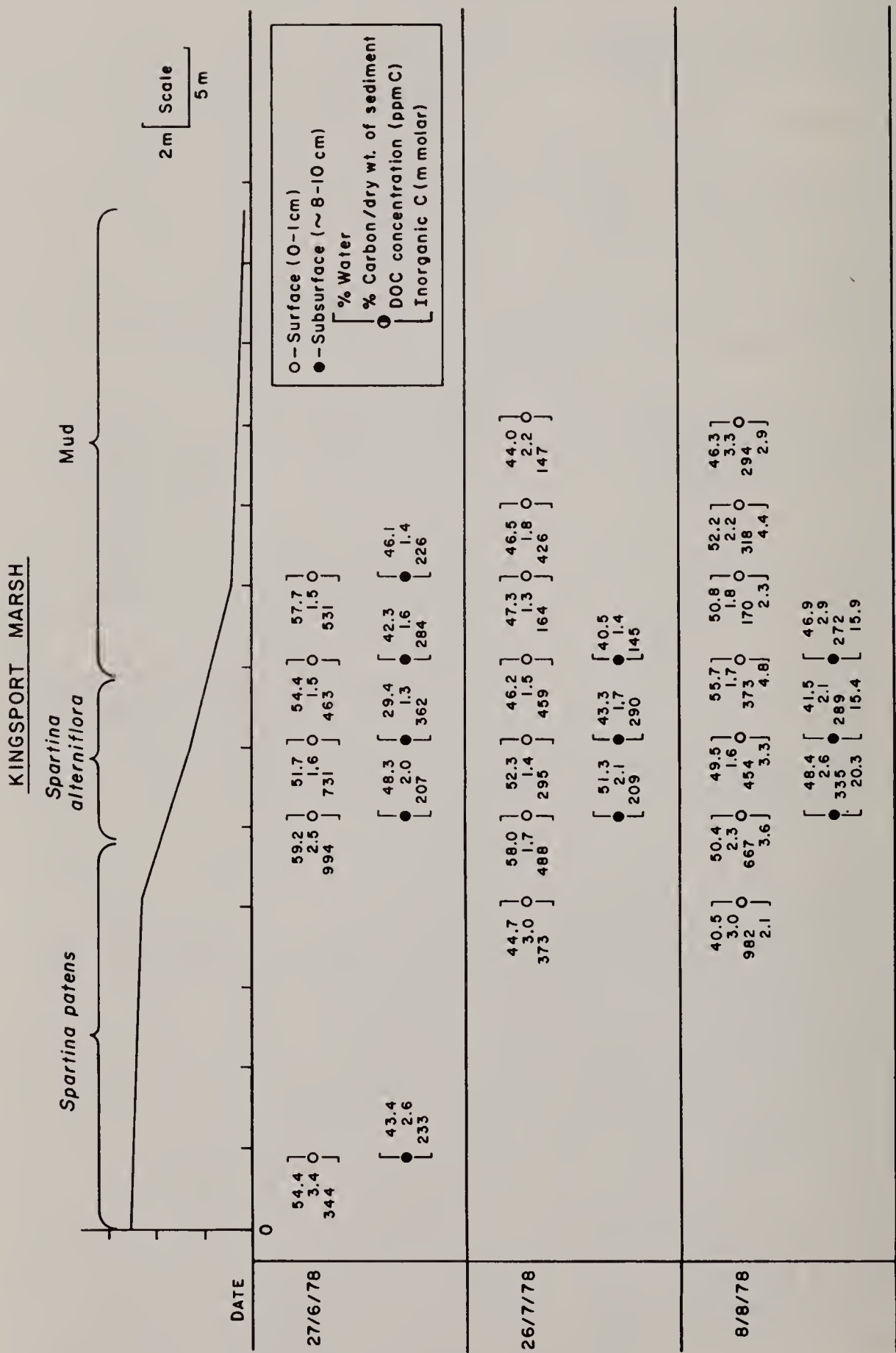


Fig 1. Cross section of Kingsport marsh on which transect was run at various times during summer of 1978. O - surface (0-1 cm) zone; ● - subsurface (8-10 cm) zone. The water content(%), carbon content of sediment (%), and DOC concentration (ppm C), and dissolved inorganic concentration (mmolar) of pore waters are shown for each sample.

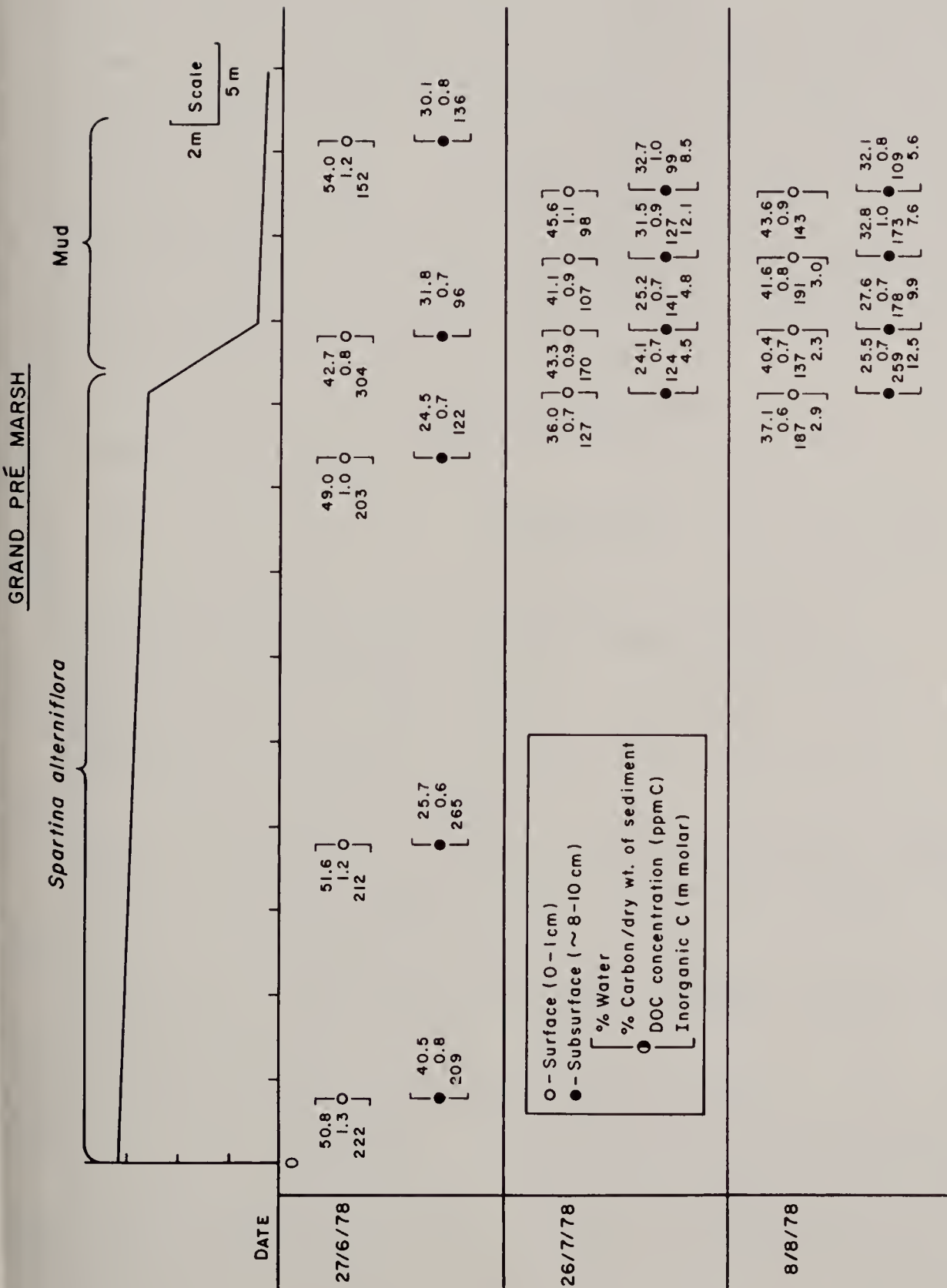


Fig 2. Cross section of Grand Pré marsh on which transect was run at various times during summer of 1978. O - surface (0-1 cm) zone; ● - subsurface (8-10 cm) zone. The water content (%), carbon content of sediment (%), and DOC concentration (ppm C), and dissolved inorganic concentration (mmolar) of pore waters are shown for each sample.

Conclusion

Concentrations of organic matter in pore waters of the marshes studied were high and variable. Average concentrations of DOC (100-300 ppm C) in the pore waters were about 2 orders of magnitude higher than the concentrations expected in the incoming tidal waters from the open Bay of Fundy (1.2-1.7 ppm C; MacKinnon & Walker, in preparation). Even in the established drainage channels of the marshes, high DOC concentrations (up to 900 ppm C) were measured in the pore waters (Fig 1), which indicates either there is little flux of organic carbon from the sediments to the tidal water or the rate of production of dissolved species in the pore waters is extremely rapid. If the former is the case, the main pathway of input of dissolved species from these marsh sediments should be by the process of diffusion (Gardner 1973) rather than advection and mixing. Because of their clay-silt nature, the sediments in these areas are highly compacted and there is probably little advective exchange between the subsurface sediments and the overlying waters. Thus, even at 5-10 cm depths, reducing zones were established with concentrations of sulfide high enough to be evident by color and odor. Diffusion is a slower process than advection and if this is the main mechanism of transport (Gardner 1973), this may explain why no dramatic changes in measured DOC concentrations were noted over the period of this study. However, there were large differences in the organic carbon content of these 2 marshes; areas which also had obvious physical and biological

Table II. Comparison of the mean results obtained on the Kingsport and Grand Pré marshes during the summer of 1978

Date	Location	Depth in core (cm)	Mean carbon content of sediment (% dry wt)	Mean water content (%)	Mean DOC concentration (ppm C)	Mean carbonate concentration (mM)
27/6/78	Kingsport	0-1	2.08 + .8	55.5 + 3.0	613 + 250	-
		8-10	1.77 + .5	42.0 + 7.4	263 + 63	-
	Grand Pré	0-1	1.08 + .2	49.6 + 6.3	219 + 55	-
		8-10	0.72 + .1	30.5 + 6.3	166 + 70	-
26/7/78	Kingsport	0-1	1.85 + .6	47.8 + 5.5	325 + 145	-
		8-10	1.72 + .3	45.0 + 5.6	215 + 72	-
	Grand Pré	0-1	0.89 + .2	41.5 + 4.0	126 + 32	-
		8-10	0.83 + .2	28.4 + 4.3	123 + 17	7.5 + 3.6
8/8/78	Kingsport	0-1	2.36 + .7	49.2 + 7.0	430 + 250	3.4 + 1.2
		8-10	2.53 + .4	45.6 + 3.6	299 + 33	17.3 + 2.7
	Grand Pré	0-1	0.74 + .1	40.7 + 2.7	165 + 28	2.9 + 0.4
		8-10	0.80 + .1	29.5 + 3.5	180 + 61	8.9 + 3

differences. The older and more developed Kingsport marsh had higher and more variable organic carbon values than were observed on the younger marsh at Grand Pré.

The estimation of input of organic matter from such marsh areas to the Bay of Fundy can not be based on the results obtained from 2 such small areas. However, it is clear from this study that concentrations of organic carbon are high in these marshes and pathways for its input into the Bay are available. The methods described in this study allow the organic matter in the sediment and their pore waters to be easily and reliably measured. Differences in the concentrations and in the variability of the parameters measured on the 2 marshes studied were large as were other properties of the marshes such as age and physical development and plant diversity. In both marshes concentrations of organic carbon were much higher than in the waters of the incoming tides and dissolved organic matter is probably exported. However, estimation of the export from the marshes will require more extensive analyses of the waters throughout tidal cycles. This should lead to a better understanding of the relation between dissolved organic matter in the marshes and production in the Bay of Fundy.

Acknowledgement

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NITROGEN FIXATION, AS DETERMINED BY ACETYLENE REDUCTION, IN TWO SALT MARSHES OF MINAS BASIN¹

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Rates of acetylene reduction to ethylene were measured and expressed as nitrogen fixation in two Minas Basin salt marshes subjected to tides of extremely high amplitude. Rates both at the soil surface and below ground were low throughout the season. The mean sub-surface rate of reduction was equivalent to about $25 \mu\text{g N m}^{-2}\text{h}^{-1}$, or 1 to 2% of the total requirements of the dominant angiosperm species (*Juncus gerardii*, *Spartina patens*, and *S. alterniflora*). At the soil surface the reduction rate was about $50 \mu\text{g N m}^{-2}\text{h}^{-1}$, and was associated mainly with species of *Oscillatoria* and *Lyngbya* in the early and mid summer, as well as with *Anabaena* in late summer. Combined nitrogen (NO_3 , NO_2 , NH_4) was high in both soil and estuarine waters, but declined somewhat during the summer, and may possibly have inhibited N_2 fixation. Thus, these marshes may not be nitrogen limited.

Introduction

Salt marshes on the Atlantic coast of North America are among the most productive, non-agricultural ecosystems in the world (Odum 1971; Seneca 1974). As the annual production of these marshes decomposes, tidal action removes much of it in particulate form (Teal 1962), providing an important nutrient pool in surrounding waters (Teal 1962; Reed & Moisan 1971; Mann 1975). Marshes also contribute dissolved organic and sometimes inorganic nitrogen (Armstrong et al. 1975; Dawson & Armstrong 1975; Heinle & Flemer 1976), phosphate (Reimold 1972), and silica (Gardner 1975) to receding tidal waters.

Halophytic grasses and phorbes are the dominant angiosperms on salt marshes, and growth of these plants may be limited by lack of nitrogen (Valiela & Teal 1974; Broome et al. 1975). The apparent incongruity of net nitrogen export from a nitrogen limited system has led to the investigation of salt marshes for N_2 fixation (Carpenter et al. 1978; Patriquin & Keddy 1978; Patriquin & McClung 1978), with 2 major sites of N_2 fixation being identified: bacteria associated with the roots of angiosperms (belowground N_2 fixation), and cyanobacteria (blue-green algae), both heterocystous (Jones 1974; Van Raalte et al. 1974; Whitney et al. 1975) and non-heterocystous (Carpenter & Price 1977; Stewart 1975; 1977) species, growing on mud surfaces. Heterotrophic bacteria in sediments have been found to fix much less nitrogen than cyanobacteria (Jones 1974, Whitney et al. 1975). Patriquin and McClung (1978)

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estimated N_2 fixation associated with the roots of *Spartina alterniflora* to be $93 \text{ kg N ha}^{-1} \text{ yr}^{-1}$ in a marsh of the Atlantic coast of Nova Scotia, equivalent to 60% of the nitrogen accumulated by *S. alterniflora*. Carpenter et al. (1978) reported similar rates for a Massachusetts marsh. Patriquin and McClung (1978) estimated N_2 fixation at the mud surface of an Atlantic coastal marsh to be $22 \text{ kg N ha}^{-1} \text{ yr}^{-1}$, attributing most of this activity to species of *Lyngbya*.

Extensive areas of salt marsh occur along the shores of Minas and Chignecto basins, at the head of the Bay of Fundy. These basins are characterized by large tidal amplitudes, rapid tidal currents, and large amounts of materials suspended in the water column (Bousfield & Leim 1960; Pelletier & McMullen 1972; Dalrymple et al. 1975). We examined 2 sites on the Minas Basin marshland, for: N_2 fixation, nitrate reductase activity of the angiosperms, and combined nitrogen content of the soils and flooding waters.

Materials and Methods

Study Sites

Two transects were established at sites on Minas Basin, both in Kings Co., N.S., one near the community of Kingsport, the other near Grand Pré. The Kingsport marsh is well established and mature; the age of Grand Pré marsh is about 15 years, being the result of recent dyking. These transects were established in the spring of 1977. Data were collected biweekly from April through August. Acetylene reduction data are from 1977 and 1978; other data are from 1978 only.

Further details of the conformation and floristic composition of these transects is in the report of Smith (1978), and will be published separately.

Soil-Surface Algae

Circular, 8 cm diameter, samples of the mud surface were taken in the vicinity of each sampling station. These were examined microscopically, and the dominant species of cyanobacteria noted.

Angiosperm Nitrogen Requirements

Aboveground angiosperm production (maximum seasonal standing crop) was measured by cutting, drying, and weighing the biomass contained in 0.25 m^2 quadrats. The percentage of nitrogen in above- and belowground tissue was determined by Kjeldahl analyses.

Acetylene Reduction Assay

Reduction of acetylene to ethylene, a widely used procedure for expressing nitrogenase activity (Carpenter et al. 1978; Patriquin & McClung 1978; Hardy et al. 1968), was measured by the in situ method as was done previously (Patriquin & Denike 1978). Acetylene (10 kPa) was generated inside each cylinder by the addition of water to calcium carbide. Areas of mud surfaces (200 cm^2) were incubated with acetylene (10 kPa) in 500 ml specimen jars, allowing separation of surface and belowground acetylene reduction. Five ml samples of gas were removed from the cylinders and jars at 2 and 26 h. Nitrogen fixation was calculated using a ratio of 3 acetylene molecules reduced for each molecule of nitrogen (N_2) assumed to be fixed (Hardy et al. 1968). As no ethylene production was detected in aerobic or anaerobic controls, the measured rates of acetylene reduction were applied directly to the calculations.

Combined Nitrogen Determinations

Water samples were collected in 500-ml acid-washed, polyvinylchloride bottles. Samples were taken from: estuarine water at the end of the Grand Pré transect, water seeping into holes (15 cm deep) dug in the marsh (soil water), and water draining out of the marsh soil. The latter was collected from small streams draining the marshes; only Zones 1, 2 and 3 of the Kingsport marsh yielded soil water. Samples were frozen on dry ice immediately, and held at -40° until analysis. Nitrate, nitrite, and ammonium were determined by the methods given in Strickland and Parsons (1972).

Assay of Nitrate Reductase Activity

Sods of *Juncus gerardii*, *Spartina patens*, and *S. alterniflora* were transported to the laboratory and held overnight in a growth chamber (25° , 16:8 h L:D, darkness commencing at 2000 h). The following day the soil was washed from the sods, and 200 mg of shoot and root tissue were taken from each. Tissue samples were chopped into 1 mm segments and incubated in darkness at 25° for 1 h in 25 ml flasks each containing: 1.6 ml 25% *n*-propanol, 3.0 ml 0.2 M KNO_3 , 1.0 ml NaOH (1 M) solution, 2.0 ml 0.5 M potassium phosphate buffer (pH 7.5), 2.4 ml water, and 0.15 g NaCl (modified from Jaworski 1971). Immediately before dark incubation, flasks containing samples were evacuated (4 withdrawals with a 50-ml syringe) and backfilled with dinitrogen.

Samples of shoot tissue were always taken from the youngest, fully expanded blade. Root tissue was taken from near the root tips. One-ml samples of the medium were removed from each flask at 0 and 60 min, and analysed for nitrite (Strickland & Parsons 1972). Dry weight of the plant material was determined after the assay.

Results

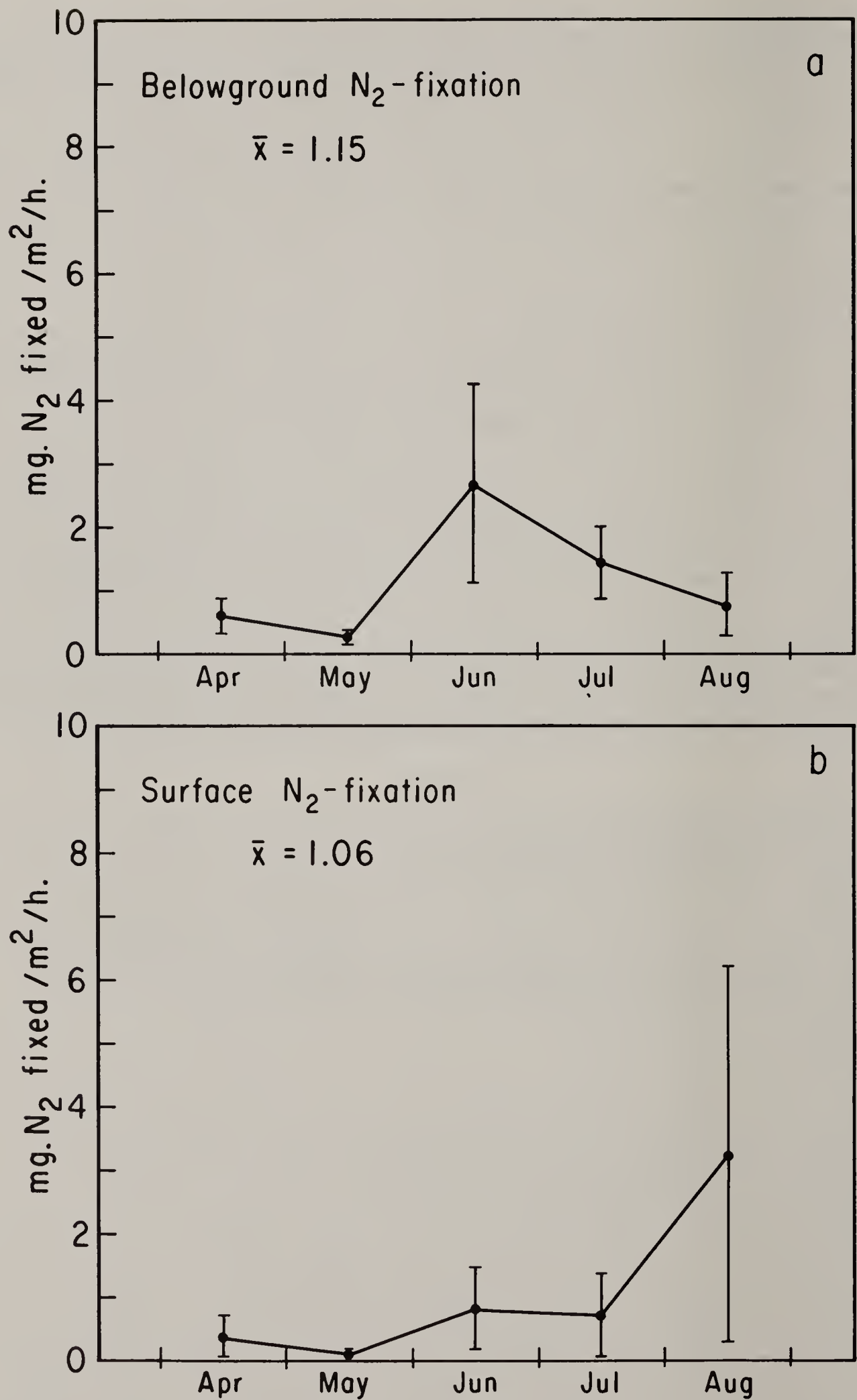
Belowground Nitrogen Fixation

On both Kingsport and Grand Pré marshes, there was a peak in N_2 fixation in spring (Figs 1 and 2). The average rates of belowground N_2 fixation were similar in both marshes, and were low compared with values reported for other Atlantic coast marshes (Table I). *Spartina alterniflora* and *J. gerardii* fixed similar amounts of nitrogen, whereas *S. patens* fixed only about one-half this amount (Table II).

Mud Surface Nitrogen Fixation

Rates of N_2 fixation by organisms on the mud surfaces of both marshes were low until late August when an abrupt increase was observed (Figs 1 and 2). From April to July, when the rates were low, species of the non-heterocystous genera, *Oscillatoria* and *Lyngbya* were the dominant cyanobacteria of the mud surfaces. In August, coincident with the sudden increase in N_2 fixation, there was an increase in biomass of *Anabaena* (Table II), with circular mats up to 20 cm in diameter appearing on the surface of the mud. These mats were more common in the lower zones of the marshes where the biomass of cyanobacteria had previously been low. One such mat reduced acetylene at the rate of $400 \mu\text{M m}^{-2} \text{ h}^{-1}$. Within 2 weeks of the last sampling, autumn storms had fragmented and to a large extent buried these mats.

The fine surface sediments of the lower zones of *S. alterniflora* are subjected to twice daily tidal resuspension, and resulting substrate instability may be responsible for low numbers of cyanobacteria and thus low rates of N_2 fixation observed in these areas. In general, surface N_2 fixation was associated with photosynthetic organisms in the sediments, and Table II lists dominant species of cyanobacteria noted on the marshes during each of the summer months.



Figs 1 and 2. Seasonal distribution of (a) belowground and (b) aboveground N₂ fixation at Grand Pré (Fig 1) and Kingsport (Fig 2). Each point is the average of 8 or 16 measurements. The vertical bars represent $\pm 25\bar{x}$. The measurements for these averages were taken during 2 summer seasons.

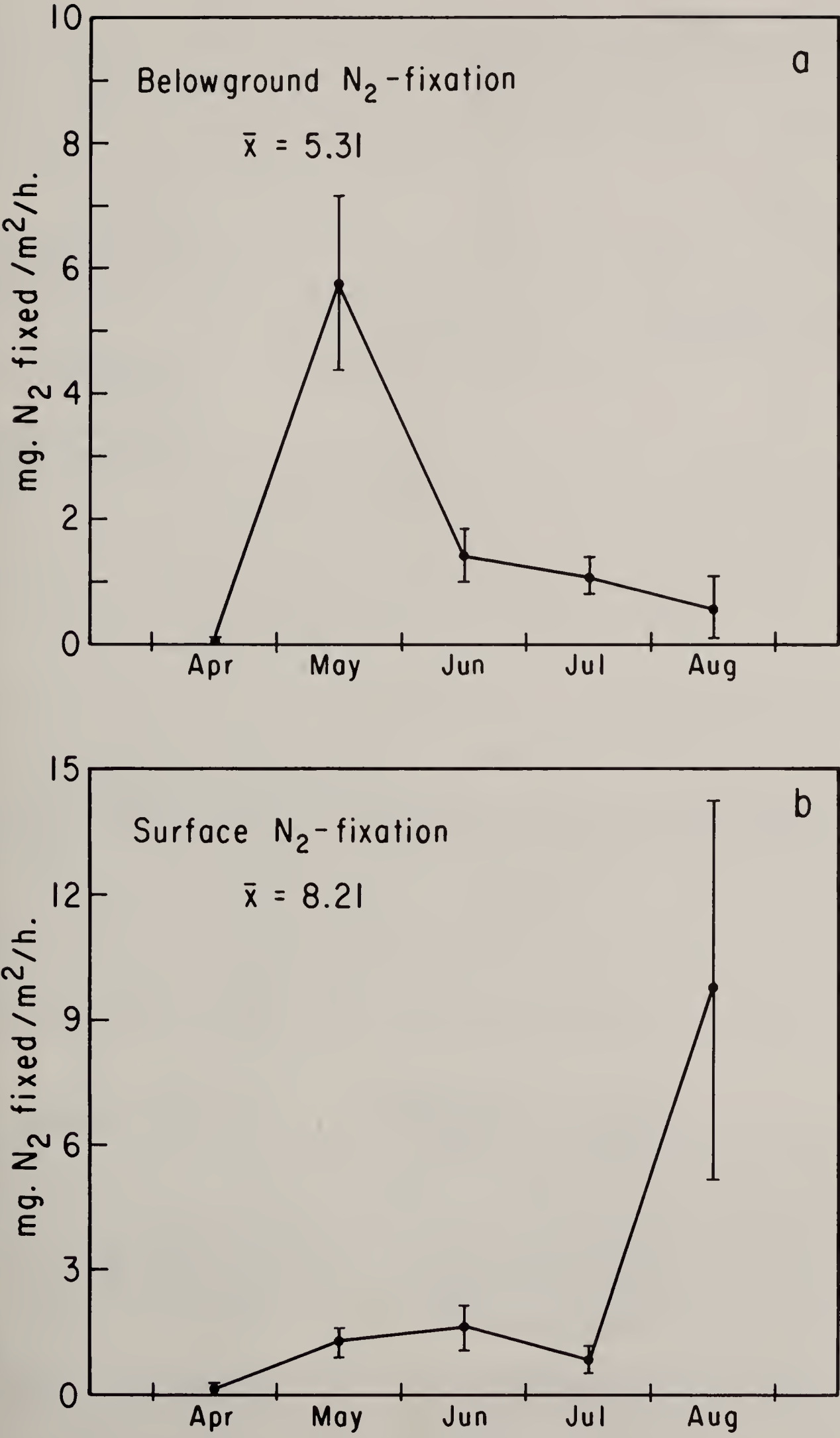


Fig. 2

Table I. Above- and belowground rates of N₂ fixation on Grand Pré, Kingsport, and several other marshes of the Atlantic coast.

Site	Grand Pré*	Kingsport*	Other
μg N m ⁻² h ⁻¹ (surface) n = 56)	66.8 ± 47.3	47.3 ± 36.5	625 (Carpenter et al. 1978) 800 (Patriquin and McClung 1978)
μg N m ⁻² h ⁻¹ (below ground) (n = 56)	28.6 ± 24.8	23.8 ± 17.8	3,300 (Carpenter et al. 1978) 3,000 (Patriquin and McClung 1978)
<i>Mud Flats</i>			
μg N m ⁻² h ⁻¹ (n = 14)	9.8 ± 9.6	15.2 ± 10.5	

* average of 2 summer seasons

Table II. Dominant species of cyanobacteria of the Kingsport and Grand Pré transects during the periods indicated.

Month	Kingsport	Grand Pré
April	<i>Oscillatoria brevis</i>	<i>Oscillatoria brevis</i>
May	<i>Oscillatoria brevis</i>	<i>Oscillatoria brevis</i>
June	<i>Oscillatoria brevis</i> <i>Oscillatoria margaritifera</i> <i>Lyngbya confervoides</i> <i>Microcoleus</i> sp	<i>Oscillatoria brevis</i> <i>Lyngbya confervoides</i>
July	<i>Oscillatoria brevis</i> <i>Oscillatoria corallinae</i> <i>Lyngbya confervoides</i> <i>Microcoleus</i> sp	<i>Oscillatoria brevis</i> <i>Oscillatoria margaritifera</i> <i>Lyngbya confervoides</i>
August	<i>Anabaena spherica</i> <i>Anabaena subcylindrica</i> <i>Oscillatoria brevis</i> <i>Oscillatoria corallinae</i> <i>Oscillatoria princeps</i>	<i>Anabaena subcylindrica</i> <i>Oscillatoria brevis</i> <i>Oscillatoria princeps</i> <i>Lyngbya confervoides</i>

The rates of N_2 fixation by organisms living on the surface of the mud beyond the angiosperms cover were comparable for the 2 study sites, and much lower than rates amongst the angiosperms (Table I). The instability of the sediments may restrict the types of species, in addition to numbers, capable of inhabiting the sediments. No cyanobacteria were noted in the mud sediments, and quite possibly N_2 fixation here was associated with heterotrophic bacteria.

Nitrogen Accretion in Angiosperms

Concentrations of nitrogen in shoot and root tissue declined throughout the sampling period (Table III), except in root tissue of *J. gerardii* which showed an abrupt increase near the end of the growing season. For all angiosperm species, belowground N_2 fixation could have supplied only 1 to 2% of the total nitrogen accumulated (Table IV).

Nitrate Reductase Activity

In the aboveground tissues of all 3 species assayed, and in belowground tissues of *J. gerardii* and *S. patens*, nitrate reductases activity (per g dry wt) declined during summer. The root tissue of *S. alterniflora*, both tall and short forms, also declined throughout most of the summer, but increased markedly in late July (Fig 3) just prior to the onset of flowering. A similar pattern of nitrate reductase activity was observed in a marsh of the Atlantic coast of Nova Scotia by Livingstone (1978), although the absolute rates observed were about 100 fold greater than ours.

Combined Nitrogen in Soil and Estuarine Waters

Concentrations of nitrate, nitrite, and ammonium, in both soil and seepage waters, declined as the growing season progressed (Table V). Nitrate in the estuarine waters also declined during this time.

We found that the concentration of nitrate in the estuary water showed a strong positive correlation with the amount of sediment suspended in the water column. This relations best fitted the line $y = 7.15 + 0.69x$, where y is the concentration of nitrate in $\mu\text{g-at } \ell^{-1}$ and x is g dry weight of sediment ℓ^{-1} ($r = 0.95$). For this reason nitrate concentrations in Table V are given in $\mu\text{g-at g dry sediment}^{-1}$. Both sediment and nitrate levels varied inversely with tide height. Sediment and nitrate concentrations were as low as 1.5g dry weight ℓ^{-1} and 7.2 $\mu\text{g-at } \ell^{-1}$, respectively, at high tide and as high as 28g dry weight ℓ^{-1} and 24 $\mu\text{g-at } \ell^{-1}$, respectively, at low tide.

Discussion

Studies of salt marshes bordering bodies of water with much smaller tidal amplitudes than the Bay of Fundy suggest that the amounts of combined nitrogen imported into these marshes each season are insufficient to account for the observed productivity. This topic has been reviewed by Hanson (1977). High levels of N_2 fixation are characteristic of these marshes (Carpenter et al. 1978; Patriquin & McClung 1978; Patriquin & Keddy 1978), and may supply the balance of the nitrogen required. Even so, these marshes are considered to be nitrogen limited (Valiela & Teal 1974; Broome et al. 1975).

The rates of belowground N_2 fixation in Minas Basin marshes are much lower than those reported for other marshes. Assuming complete transfer of fixed nitrogen from rhizosphere bacteria to the host angiosperm, nitrogen from this source, based on our in situ measurements, should supply only 1 to 2% of the requirements of the higher plants. Even if the rate is 5-fold higher as suggested by Patriquin & Denike

Table III Percent nitrogen in above- and belowground angiosperm tissue at various times during the summer. Each value is the average of 2 replicates differing at most from each other by 3%.

Zone	Tissue	Percent Nitrogen				Species
		June 14	July 12	July 27	August 9	
KP1*	Shoot	2.15	1.38	1.01		<i>Juncus gerardii</i>
	Root	0.95	0.38	1.14		
KP2*	Shoot	1.03	0.95		0.60	<i>Spartina patens</i>
	Root	0.93	0.83		0.74	
KP4*	Shoot	2.11	1.02		0.97	<i>Spartina alterniflora</i> (tall form)
	Root	1.66	1.21		1.09	
GP2**	Shoot	1.92	1.34		0.95	<i>Spartina alterniflora</i> (short form)
	Root	0.79	0.74		0.55	

* Kingsport

** Grand Pré

Table IV. Comparison of annual accumulation of nitrogen in angiosperms with total annual nitrogen fixation.

Species	% N at max biomass		g m ⁻² yr ⁻¹		N fixed x 100	
	Shoot	Root	N accumulated		N accumulated	
<i>Juncus gerardii</i>	1.38	0.83	13.39	0.210		1.57
<i>Spartina patens</i>	0.60	0.74	9.19	0.137		1.49
<i>Spartina alterniflora</i>	0.99	0.76	13.62	0.243		1.78

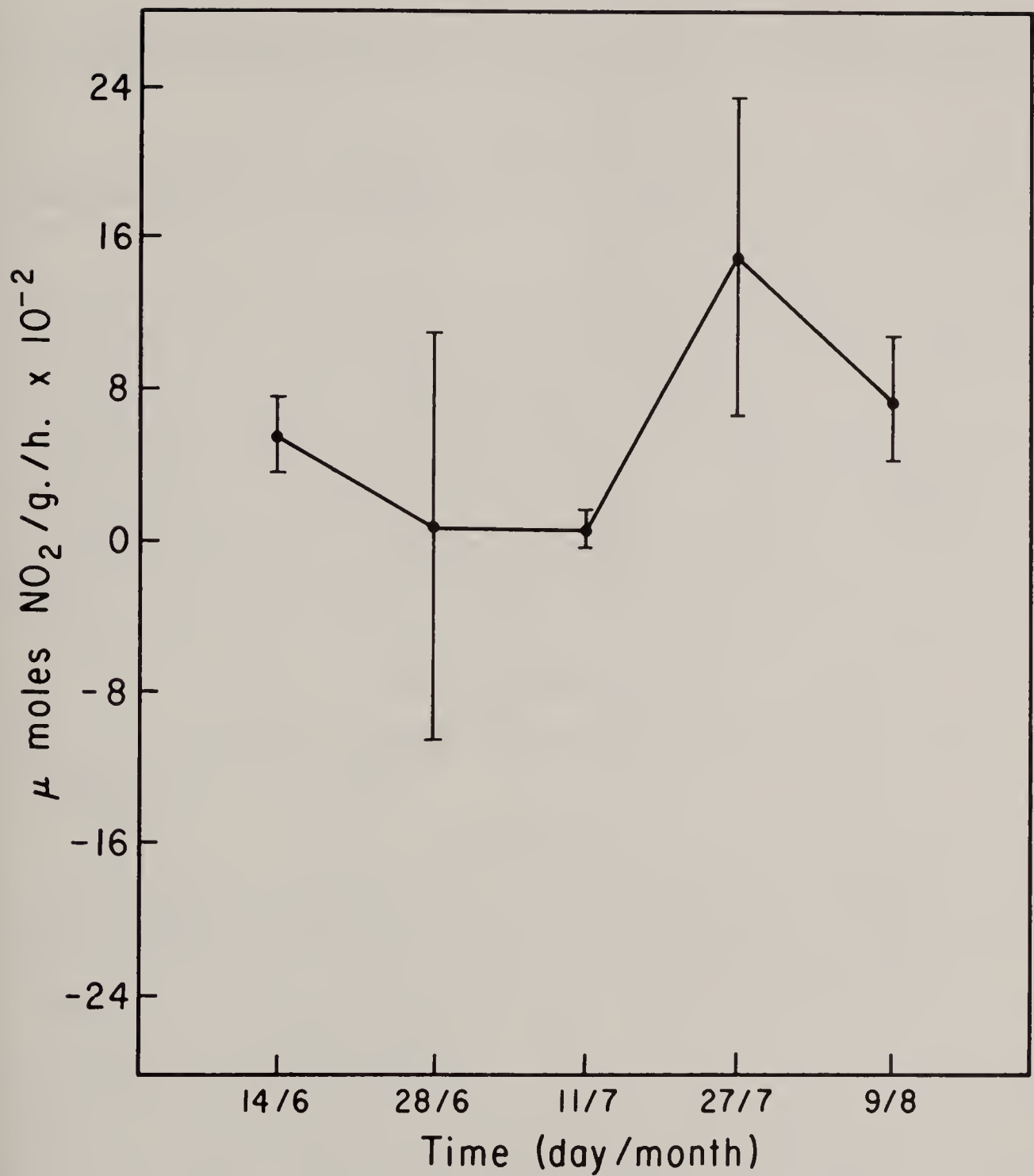


Fig 3. The seasonal distribution of nitrate reductase activity in the root tissue of *S. alterniflora* from zone 4 of the Kingsport marsh. The points are the averages of 3 values and are given $\pm 25\bar{x}$.

(1978), nitrogen fixed belowground in Minas Basin marshes could have supplied only about 7.5% of the angiosperm requirement.

Nitrogen fixation is suppressed by some forms of combined nitrogen (Shanmugam & Morand 1974; Burns & Hardy 1975), and suppression in situ by ammonium may occur in some marshes (Patriquin & Keddy 1978). The large tidal amplitudes of Minas Basin results in rapidly flowing currents, large loads of suspended matter, and complete mixing of the water column. This is probably the cause of the high concentrations of combined nitrogen in soil and estuarine waters which may possibly supply the nitrogen requirements of the marsh angiosperms and inhibit N₂ fixation. It is further possible that the high levels of ammonium and nitrate observed in the reducing marsh soils supply much of the angiosperms nitrogen and bring about the low rates of nitrate reductase activity observed in these plants (Fig. 2).

The lower levels of combined nitrogen in the soil and estuarine waters during late

Table V. Concentration of combined nitrogen in soil water, drainage water, and estuarine water of the Kingsport marsh during the summer season.

		Soil water ($\mu\text{g-at } \ell^{-1}$)		
Zone	Date	Nitrate	Nitrite	Ammonium
1	6 June	21.0 + 2.8	10.7 + 1.2	1.1 + 0.2
1	7 July	18.9 + 0.6	7.6 + 0.6	0.8 + 0.1
2	28 June	14.9 + 1.1	7.3 + 0.2	0.3 + 0.4
2	27 July	12.1 + 0.7	6.7 + 0.3	0.1 + 0.0
3	12 July	9.8 + 0.8	3.5 + 0.7	0.1 + 0.0
3	27 July	5.2 + 0.1	1.3 + 0.2	Trace

		Drainage water ($\mu\text{g-at } \ell^{-1}$)		
Site	Date	Nitrate	Nitrite	Ammonium
Kingsport	28 June	14.5 + 5.7	3.6 + 0.1	0.03 + 0.01
Kingsport	27 July	9.2 + 0.1	3.2 + 0.2	0.02 + 0.01
Grand Pré	14 June	29.6 + 0.3	11.1 + 0.1	1.2 + 0.1
Grand Pré	27 July	14.7 + 0.1	5.5 + 0.9	1.1 + 0.1

		Estuarine water	
Date		$(\mu\text{g-at NO}_3 \text{ g sediment dry wt}^{-1})$	
June 14		93.0	91.2
July 11		85.1	81.1
July 27		73.4	71.3
August 9		55.5	53.3

Values are the average of 3 measurements and are given $\pm 25\bar{x}$.

summer may have conferred a slight advantage to the more efficient N_2 -fixing heterocystous cyanobacteria, resulting in the proliferation of *Anabaena* in August. However, similar changes in species composition have not been noted on other marshes.

As with belowground N_2 fixation, the amounts of nitrogen fixed at the marsh surface during the growing season was low (Table I). Here again it is likely that high levels of combined nitrogen in the marsh soils and estuarine waters inhibited N_2 fixation.

The nitrate-sediment correlation was surprising as nitrate concentrations were determined after the water samples had been filtered. Possibly nitrate ions are associated with positively charged ions bound to the clay particles suspended in the water, and they are removed during the filtration process.

We suggest that, unlike salt marshes on the Atlantic coast of the province, Minas Basin marshes are not nitrogen limited. The rapidly flowing tidal currents of the Basin result in high levels of combined nitrogen in the water column. This in turn results in high levels of soil nitrogen in the marshes which supplies most of the requirements of the marsh species. However, data presented by Smith (1978) suggest that other factors may limit productivity on these marshes.

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FUNGI FROM THE SALT MARSHES OF MINAS BASIN, NOVA SCOTIA

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Ascomycete and Deuteromycete species growing on *Spartina alterniflora* Loisel., *S. patens* (Ait.) Muhl., and wood blocks were examined from the salt marshes bordering on Minas Basin, Kings Co., N.S. These collections were obtained from four salt marshes and 10 intertidal salt marsh pools. Twelve Ascomycetes, 10 Deuteromycetes, and 1 Basidiomycete are reported with 9 of these species being new records for Nova Scotia.

Introduction

This investigation of the marine fungi of Nova Scotia was preceded by 4 studies (Meyers & Reynolds 1959; 1960; Moore & Meyers 1962; Neish 1970) that considered the lignicolous marine fungi of the province. However, little attention was given to the presence and diversity of fungi inhabiting substrate other than wood.

Gessner (1977; 1978) and Gessner and Goos (1973a; b) conducted a thorough investigation into the fungal decomposition of *Spartina alterniflora* Loisel. on the salt marshes of Rhode Island. Gessner and Kohlmeyer (1976) examined the geographical distribution of filamentous fungi from species of *Spartina* of the salt marshes along the eastern coasts of North and South America. From their 12 collection sites in eastern Canada, they reported the presence of *Buergenerula spartinae* Kohlm. et Gessner, *Leptosphaeria albopunctata* (Westend.) Sacc., *L. marina* Ellis et Everh., *L. neomaritima* Gessner et Kohlm., *Lulworthia* spp, *Mycosphaerella* sp II, *Phaeosphaeria typharum* (Desmaz.) Holm., *Phoma* sp, *Pseudorobillarda* sp, *Stagonospora* sp II, and *Cladosporium* spp. No indication of their geographical distribution within eastern Canada was given. A compilation of higher filamentous fungi growing on marine *Spartina* spp. was also reported (Gessner & Kohlmeyer 1976).

Minas Basin lies at the extreme north-east end of the Bay of Fundy in the north-central region of Nova Scotia, and because of the extreme high tides and extensive salt marshes, it offers a unique habitat for the development of fungi on wood and species of *Spartina*. These salt marshes also contain intertidal pools that present an opportunity for a comparative study of the fungal flora in another type of marsh habitat.

Materials and Methods

Collections of living and dead *Spartina alterniflora* Loisel. and *S. patens* (Ait.) Muhl. were taken from both marsh areas and intertidal pools. Collections were placed in polyethylene bags and incubated at room temperatures (21-26°C) until critically examined. Samples were taken on 9 August 1975 and on 9 November 1975 and were incubated for 49 and 48 days respectively. Locations of the collection sites are presented in Figures 17 to 20.

For the investigation of lignicolous fungi, wooden blocks (*Picea sp*) measuring 10 x 12.5 x 2.5 cm were attached to wooden stakes measuring approximately 4 x 50 x 1.5 cm. They were autoclaved at 121°C for one half h on 3 consecutive days (Johnson & Sparrow 1961). On 9 August 1975, 2 blocks were submerged in each of 10 pools by pushing the stake into the soft mud that formed the substrate. On 9 November 1975, 13 of the 20 blocks were recovered and put into polyethylene bags. At the laboratory the blocks were gently scraped and washed with distilled water to remove dense algal growths. They were then incubated for 47 days in autoclaved, interlocking glass dishes.

Squash mounts of sporocarps in sea water of 30 ‰ were adequate for most identifications. Permanent slides were prepared in Turtox mounting medium and in lactophenol-cotton blue sealed with fingernail polish (Munk 1957). Unused material

Table 1. Distribution of fungal species within study areas and pools.

Species	Pools										Study Areas			
	1	2	3	4	5	6	7	8	9	10	A	B	C	D
Ascomycetes														
1. <i>Buergenerula spartinae</i>			a	a							a	a		
2. <i>Haligena spartinae</i>											b	b		
3. <i>Halosphaeria hamata</i>	b	b										b		
4. <i>H. mediosetigera</i>				c										
5. <i>Leptosphaeria albopunctata</i>											b			
6. <i>L. contecta</i>					b			b	c		b	a		b
7. <i>L. obiones</i>	a		a	a				b			b	c	c	b
8. <i>L. pelagica</i>													c	
9. <i>Lignincola laevis</i>				c	b	a	a		b		b	b	b	b
10. <i>Lulworthia</i> spp.	b	b	a	c	c	c	c	b	c	b		b	a	
11. <i>Nais inornata</i>					b	b	b	b						
12. <i>Phaeosphaeria typharum</i>		c		b	b	a	b			c	b	b		b
Deuteromycetes														
13. <i>Alternaria alternata</i>					b				b	b			b	
14. <i>Humicola alopallonella</i>	b		b			b	b							
15. <i>Penicillium</i> spp.		b			b			b					b	
16. <i>Pestalotia</i> sp.											a			
17. <i>Phoma</i> spp.		b	a	c	b	a	b	b			a	a		
18. <i>Stachybotrys atra</i>									b					
19. <i>Stagonospora</i> spp.		a					b			c	b			
20. <i>Stemphylium maritimum</i>								b						
21. <i>Trichoderma</i> spp.								b					b	
22. <i>Zalerion maritimum</i>	b													
Basidiomycetes														
23. <i>Coprinus</i> sp.													b	b

a = present on 9 August 1975; B = present on 9 November 1975; and c = present on both collection dates.

was stored in 10% glycerin-sea water with 0.1 g copper sulfate per 100 ml (Johnson & Sparrow 1961). These collections were recently reexamined and dried for placement in the E.C. Smith Herbarium, Acadia University (ACAD). In some cases identified species are not represented in the herbarium because of lack of material.

Results

Fungi collected from the salt marshes and intertidal pools are listed in Table I, together with their distribution and collection dates. Table II presents the substrates for each collection.

Fungi not previously recorded from Nova Scotia are *Buergenerula spartinae* Kohlm. et Gessner, *Halosphaeria mediosetigera* Cribb et. Cribb, *Leptosphaeria con-*

Table II. Substrates from which fungi were collected.

Species	Substrate			
	Sa	Sp	Wd	Cm
Ascomycetes				
1. <i>Buergenerula spartinae</i>	+			
2. <i>Haligena spartinae</i>	+			
3. <i>Halosphaeria hamata</i>	+	+		
4. <i>H. mediosetigera</i>	+		+	
5. <i>Leptosphaeria albopunctata</i>	+			+
6. <i>L. contecta</i>	+			
7. <i>L. obiones</i>	+	+		+
8. <i>L. pelagica</i>	+			
9. <i>Lignincola laevis</i>	+			
10. <i>Lulworthia</i> spp.	+		+	+
11. <i>Nais inornata</i>	+			+
12. <i>Phaeosphaeria typharum</i>	+	+		+
Deuteromycetes				
13. <i>Alternaria alternata</i>	+		+	+
14. <i>Humicola alopallonella</i>			+	
15. <i>Penicillium</i> spp.	+		+	+
16. <i>Pestalotia</i> sp.				+
17. <i>Phoma</i> sp.	+		+	
18. <i>Stachybotrys atra</i>			+	
19. <i>Stagonospora</i> spp.	+			
20. <i>Stemphylium maritimum</i>	+			
21. <i>Trichoderma</i> spp.	+		+	+
22. <i>Zalerion maritimum</i>			+	
Basidiomycetes				
23. <i>Coprinus</i> sp.				+

Sa = *Spartina alterniflora*; Sp = *Spartina patens*; Wd = wood; Cm = culm material , plant species not identified

tecta Kohlm., *L. obiones* (Crouan et Crouan) Sacc., *Lignincola laevis* Höhnk., *Nais inornata* Kohlm., *Phaeosphaeria typharum* (Desm.) Holm., *Humicola alopallonella* Meyers et Moore, and *Stemphylium maritimum* Johnson. *Stachybotrys atra* Corda is known from terrestrial habitats in Nova Scotia.

All of these fungi, with the exceptions of *Buergenerula spartinae*, *Phaeosphaeria typharum* (previously reported by Gessner and Kohlmeyer 1976), and *Humicola alopallonella* (previously reported by Hughes 1968) are also new records for eastern Canada as occurring in marine environments.

New records of fungi growing on species of *Spartina* are *Halosphaeria mediosetigera* Cribb et Cribb, *Leptosphaeria contecta* Kohlm., and *Coprinus* sp. (Pers. ex) Gray.

Fungal species that occurred on the marshes and not in the pools are *Haligena spartinae* Jones, *Leptosphaeria albopunctata* (Westend.) Sacc., *L. pelagica* Jones, and *Coprinus* sp. (Pers. ex) Gray.

Fungi occurring primarily in the intertidal pools are *Halosphaeria mediosetigera* Cribb et Cribb, *Lulworthia* spp, *Nais inornata* Kohlm., *Halosphaeria hamata* (Höhnk.) Kohlm., *Alternaria alternata* (Fr.) Keissl., *Humicola alopallonella* Meyers et Moore, *Penicillium* spp, *Phoma* spp, *Stachybotrys atra* Corda, *Stagonospora* spp, *Stemphylium maritimum* Johnson, and *Zalerion maritimum* (Linder) Anastiou. The remainder of the species reported were found in both habitats.

Taxonomic Section

ASCOMYCETES

- (1) *Buergenerula spartinae* Kohlm. et Gessner: Can. J. Bot. 54: 1759. 1976. Fig 1.
- (2) *Haligena spartinae* Jones: Trans. Brit. Mycol. Soc. 45: 245. 1962. Fig 2.
- (3) *Halosphaeria hamata* (Höhnk) Kohlm.: Can. J. Bot. 50: 1951. 1972. Fig 3.
- (4) *Halosphaeria mediosetigera* Cribb et Cribb: Pap. Univ. Queensland Dept. Bot. 3: 100. 1956. Fig 4.
- (5) *Leptosphaeria albopunctata* (Westend.) Sacc.: Sylloge Fungorum 2: 72. 1883. Fig 5.

Johnson (1956) and Kohlmeyer & Kohlmeyer (1964-69) described this species as 5 to 7 septate. Neish (1970) reported a Nova Scotian collection from wood that was 6 to 8 septate, with the 8 septate condition being rare. In the collections we examined from *Spartina alterniflora*, 8-septate ascospores were common, and two 9-septate spores were observed.

- (6) *Leptosphaeria contecta* Kohlm.: Nova Hedwigia 6: 314. 1963. Fig 6.
- (7) *Leptosphaeria obiones* (Crouan et Crouan) Sacc.: Sylloge Fungorum 2: 24. 1883. Fig 7.

Previous reports (Gessner & Goos 1973a; b) of this fungus were as *L. discors* (Sacc. et. Ellis) Sacc. et Ellis, which Gessner and Kohlmeyer (1976) considered to be a synonym of *L. obiones*.

- (8) *Leptosphaeria pelagica* Jones: Trans. Brit. Mycol. Soc. 45: 105. 1962. Fig 8.
- (9) *Lignincola laevis* Höhnk.: Veröffentl. Inst. Meeresforsch., Bremerhaven, 3: 216. 1955. Fig 9.
- (10) *Lulworthia* spp. Sutherland: Trans. Brit. Mycol. Soc. 5: 259. 1916.

We did not attempt to identify these species because, as Gessner and Kohlmeyer (1976) note, this genus requires critical revision. Hughes (1975) presents a review of the taxonomic problems involved. Ascospores of the Nova Scotian material measured 280-370 x 2.5-5.0 μm .

- (11) *Nais inornata* Kohlm.: Nova Hedwigia 4: 409. 1962. Fig 10.
- (12) *Phaeosphaeria typharum* (Desm.) Holm.: Symb. Bot. Upsal. 14 (3). 1957. Fig 11.

In a previous study (Gessner & Goos 1973b) of this species occurring on species of *Spartina*, this fungus was reported as *Leptosphaeria typharum* (Rabenh.) Karst. Gessner and Kohlmeyer (1976) have pointed out that this name is a synonym of *P. typharum*.

DEUTEROMYCETES

- (13) *Alternaria alternata* (Fries) Keissler: Beih. Bot. Centr. 29: 434. 1912. Fig 12.
- (14) *Humicola alopallonella* Meyers et Moore: Amer. J. Bot. 47: 346. 1960. Fig 13.
- (15) *Penicillium* spp. Link: Sp. Pl. Fung. 1: 69. 1824.
- (16) *Pestalotia* sp. deNot: Mem. R. Acad. Sci. Torino II, 3: 80. 1839.
- (17) *Phoma* spp. (Fries) Desm.: Nat. Crypt. 13:6, 1846; Sacc., Michelia 2:4. 1880.

Many of the *Phoma* species are imperfect stages of other fungi, primarily Ascomycetes. The perfect stage is needed before the identification can be completed (Gessner & Kohlmeyer 1976).

- (18) *Stachybotrys atra* Corda: Icon. Fung. 1:21. 1837. Fig 14.
- (19) *Stagonospora* spp. Sacc.: Syll. Fung. 3: 445. 1884.
- (20) *Stemphylium maritimum* Johnson: Mycologia 48: 841. 1956. Fig 15.
- (21) *Trichoderma* spp. Pers. ex Fr.: Systema Myc. III. 214. 1829.
- (22) *Zalerion maritimum* (Linder) Anastasiou: Can. J. Bot. 41: 1135. 1963. Fig 16.

BASIDIOMYCETES

- (23) *Coprinum* sp. (Pers. ex) Gray: Nat. Arr. Brit. pl. 1: 632. 1821.

While incubating the collection bags, 3 sporocarps of a *Coprinus* sp developed within the bags. Attempts to culture the material failed.

Discussion

Gessner (1977) suggested that the presence of fungi on *Spartina alterniflora* appeared to be related more to the condition of the host plant than to temperature, salinity, or latitude. Gessner and Kohlmeyer (1976) reported the same tendency in their study of the geographical distribution of fungi growing on species of *Spartina*. Thus, Gessner (1977) proposed that there may be a characteristic fungal flora associated with species of *Spartina*, particularly *S. alterniflora*.

The results from this study are similar to those of Gessner (1977) and Gessner and Goos (1973a; b). Fungi common to both studies are *Buergenerula spartinae*, *Haligena spartinae*, *Halosphaeria hamata*, *Leptosphaeria albopunctata*, *L. obiones*, *Lulworthia* spp, *Nais inornata*, *Phaeosphaeria typharum*, *Penicillium* spp, *Phoma* spp, and *Stagonospora* spp. The fungi most frequently found in the Rhode Island study were *Alternaria* spp, *Buergenerula spartinae*, *Leptosphaeria obiones*, *Phaeosphaeria typharum*, *Phoma* sp, and *Stagonospora* sp. (as *Septoria* sp). The more common fungi from Minas Basin were *Buergenerula spartinae*, *Leptosphaeria obiones*, *Lignincola laevis*, *Lulworthia* spp, *Phaeosphaeria typharum*, and *Phoma* spp. Meyers (1974) and Meyers et al. (1970) reported a predominate fungal flora of *Cephalosporium*, *Fusarium*, *Leptosphaeria*, *Lulworthia*, *Nigrospora*, and *Phoma* from the Gulf of Mexico salt marshes indicating some variability in the mycoflora between the Atlantic seacoast and the Gulf of Mexico.

Salinity of the water flooding the marshes varied greatly, especially in areas A and D (see Fig 17) where estuarine waters are mixed with the freshwaters of the Cornwallis River. Differences of distribution between the marshes were not apparent. These data agree with Gessner (1977) who suggested that host condition was more important to fungal distribution than temperature or salinity.

Spartina alterniflora growing in the pools harbored a wider diversity of fungi than plants on the open marsh. The pattern was quite consistent for aerial parts of the

plant, but a different mycota was evident on the bases of plants growing in the water of the pools. This was a more suitable habitat for the development of typically marine species.

The only exclusively lignicolous species collected in the pools (on wood blocks) were *Humicola alopallonella*, *Stachybotrys atra*, and *Zalerion maritimum*. We did not attempt to collect lignicolous species from the open marsh.

Seasonal differences in the abundance of certain fungi were found. The only time *Buergenerula spartinae*, *Halosphaeria mediosetigera*, and *Leptosphaeria albopunctata* were collected was on 9 August 1975. Gessner (1977) found that *L. albopunctata* occurred only during June and July. However, he found that *Buergenerula spartinae* could be found on virtually 100% of the *Spartina* plants from September to April.

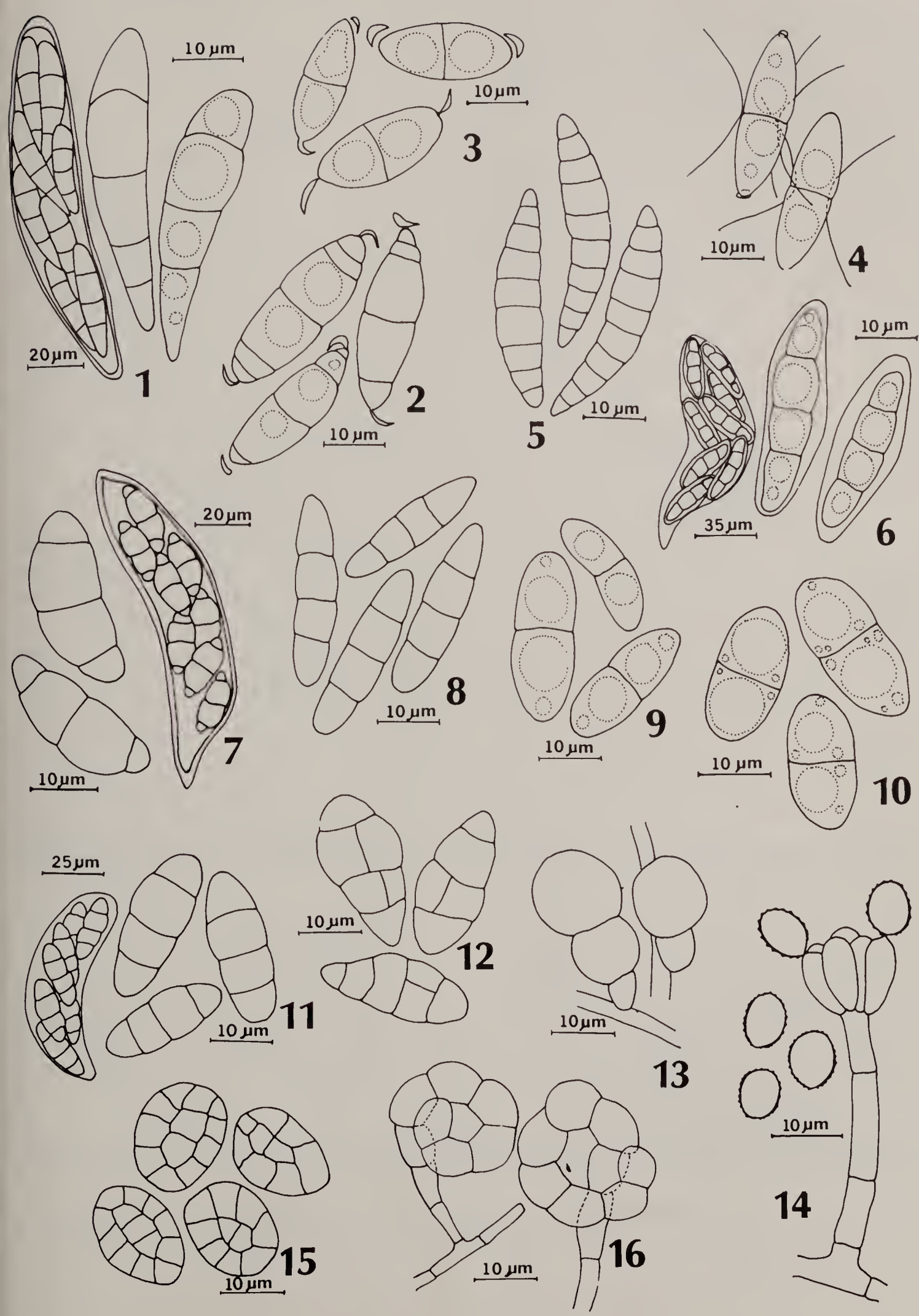
Fungi present on the 9 November 1975 collection were *Haligena spartinae*, *Halosphaeria hamata*, *Leptosphaeria albopunctata*, *Nais inornata*, *Alternaria alternata*, *Pencillium* spp, *Stemphylium maritimum*, *Trichoderma* spp, and *Coprinus* sp. Gessner (1977) found that *Halosphaeria hamata* was most common in September, *Alternaria alternata* in November, and *Leptosphaeria albopunctata* in June. *H. hamata* and *L. albopunctata* were not collected after September in a 2-year study by Gessner.

Gessner (1977) related seasonal patterns of fungal abundance to the developmental stages of *Spartina alterniflora*. In the spring, plants are invaded by weakly parasitic fungi; i.e., *Buergenerula spartinae*, *Phoma* spp, and *Phaeosphaeria typharum* (Gessner & Goos 1973b). Our data confirms that of Gessner and Goos (1973b). The above are followed by saprophytic fungi associated with the senescent leaves and inflorescences; the fungi we found were *H. hamata*, *L. albopunctata*, *L. obiones*, *L. laevis*, and *P. typharum*. These were followed by a variety of terrestrial and marine Ascomycetes on the dead standing plants and drift culm material. Fungi present were *Haligena spartinae*, *Leptosphaeria obiones*, *L. pelagica*, *Lulworthia* spp, and *Nais inornata*. The presence of such lignicolous species as *Halosphaeria mediosetigera*, *Lulworthia* spp, *Alternaria alternata*, and *Coprinus* sp suggests that these culms may be subjected to fungal attack similar to that of wood.

Gessner and Kohlmeyer (1976) have questioned whether fungi isolated by plate and moist chamber incubation techniques are normally active in a marine environment. Further studies are necessary to determine the role of fungi in the decomposition of organic matter in salt marshes.

- | | |
|--------|---|
| Fig 1 | <i>Buergenerula spartinae</i> , ascus and ascospores. |
| Fig 2 | <i>Haligena spartinae</i> , ascospores. |
| Fig 3 | <i>Halosphaeria hamata</i> , ascospores. |
| Fig 4 | <i>Halosphaeria mediosetigera</i> , ascospores. |
| Fig 5 | <i>Leptosphaeria albopunctata</i> , 8 and 9 septate ascospores. |
| Fig 6 | <i>Leptosphaeria contecta</i> , ascus and ascospores. |
| Fig 7 | <i>Leptosphaeria typharum</i> , ascus and ascospores. |
| Fig 8 | <i>Leptosphaeria pelagica</i> , ascospores. |
| Fig 9 | <i>Lignicola laevis</i> , ascospores. |
| Fig 10 | <i>Nais inornata</i> , ascospores. |
| Fig 11 | <i>Phaeosphaeria typharum</i> , ascus and ascospores. |
| Fig 12 | <i>Alternaria alternata</i> , conidia. |
| Fig 13 | <i>Humicola alopallonella</i> , conidia and conidiophore. |
| Fig 14 | <i>Stachybotrys atra</i> , conidia and conidiophore. |
| Fig 15 | <i>Stemphylium maritimum</i> , conidia. |
| Fig 16 | <i>Zalerion maritimum</i> , conidia and conidiophore. |

Figures 1 to 16 were prepared from camera lucida drawings.



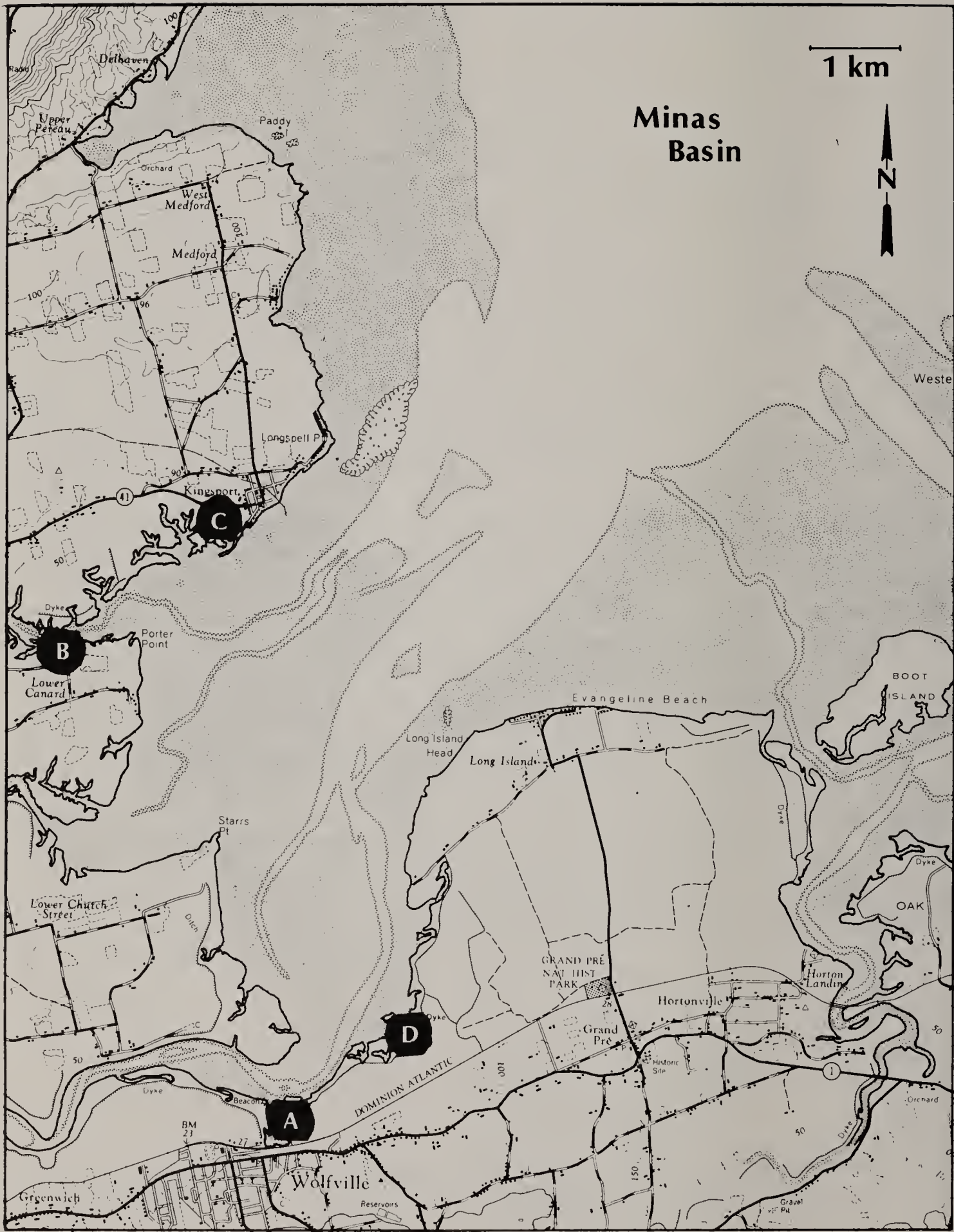


Fig 17 Map of southwest Minas Basin illustrating study areas A-D, prepared from Dept. of Energy, Mines, and Resources map 21H/1W-edit. 4ASE-Ser. A791-1967.

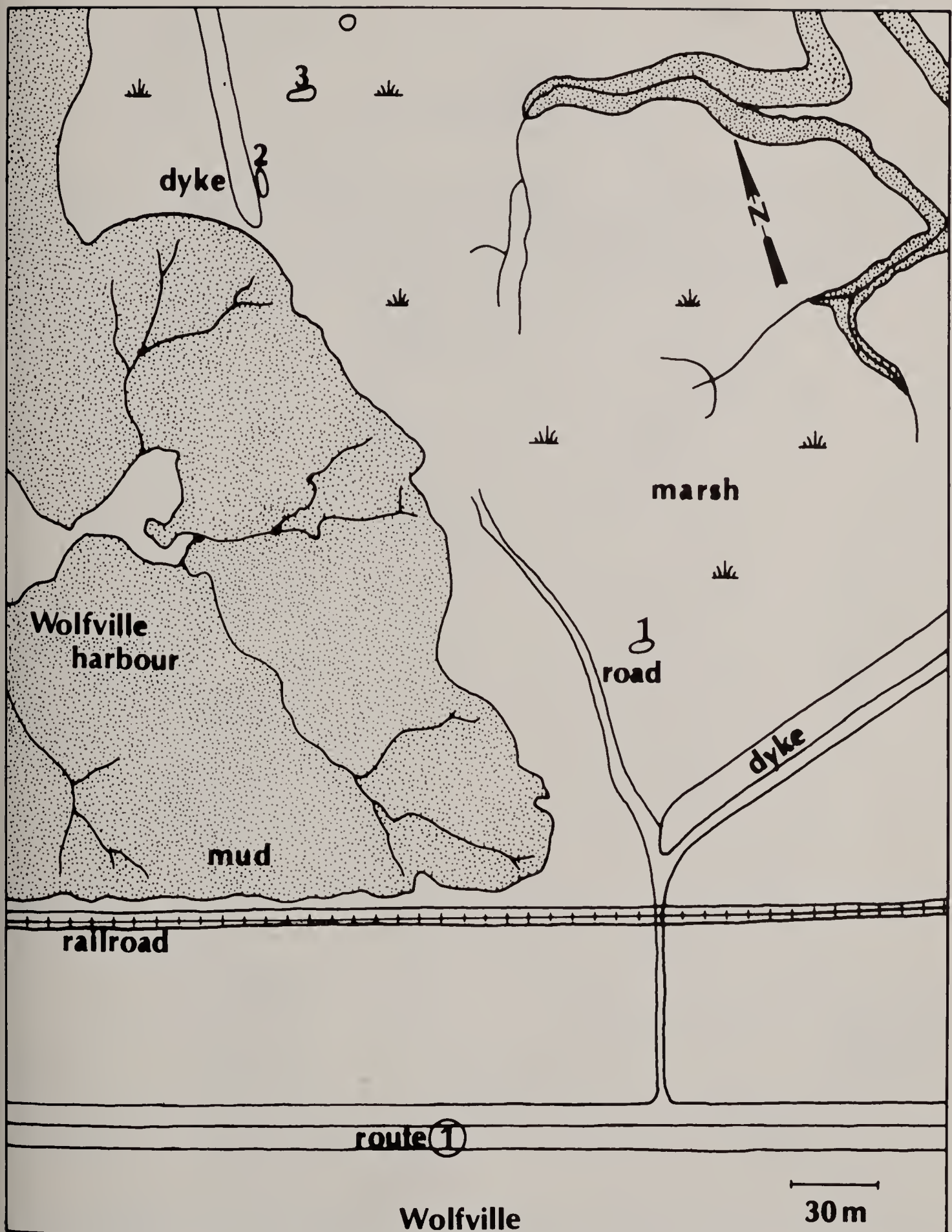


Fig 18 Study area A, location of pools 1-3.

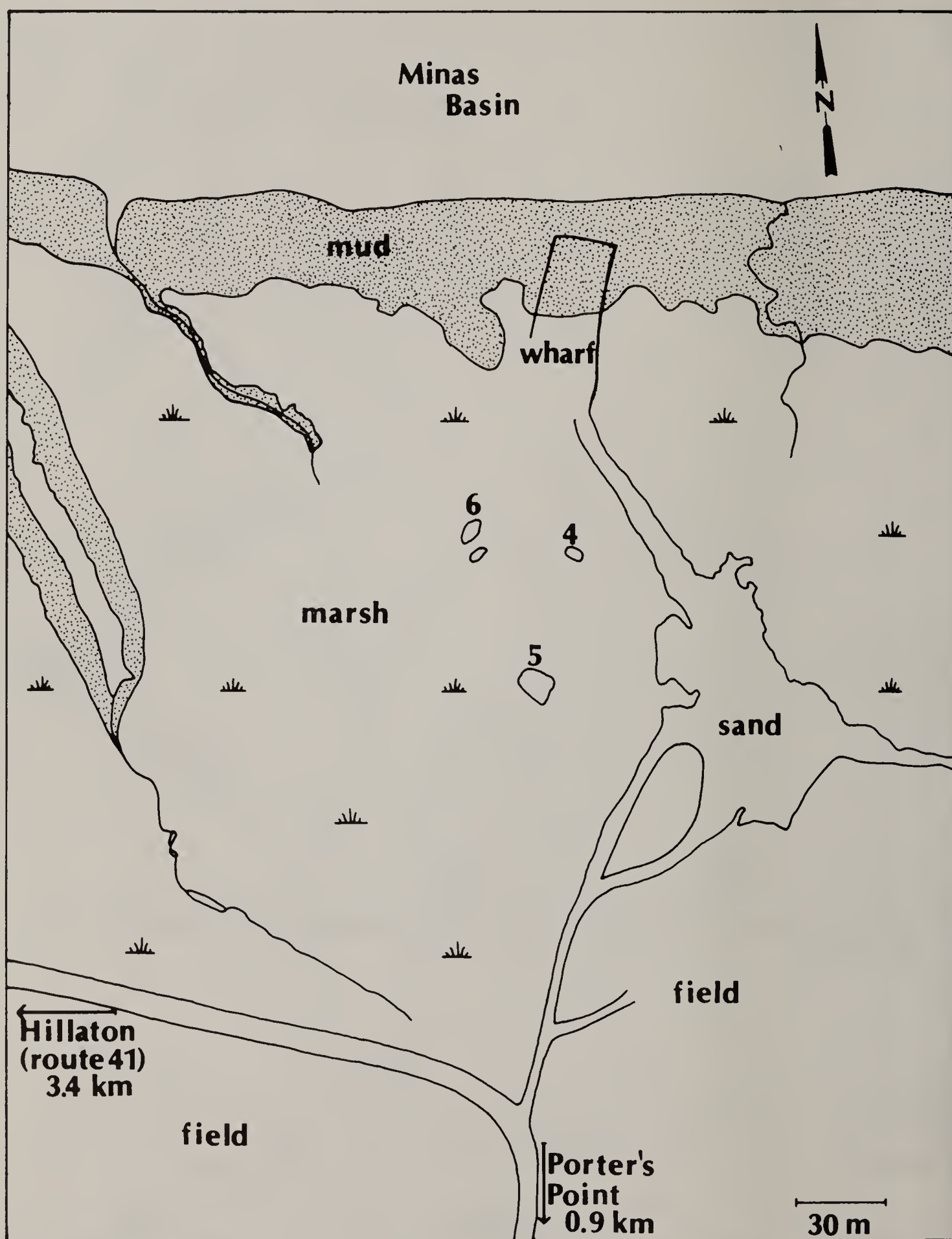


Fig 19 Study area B, location of pools 4-6.

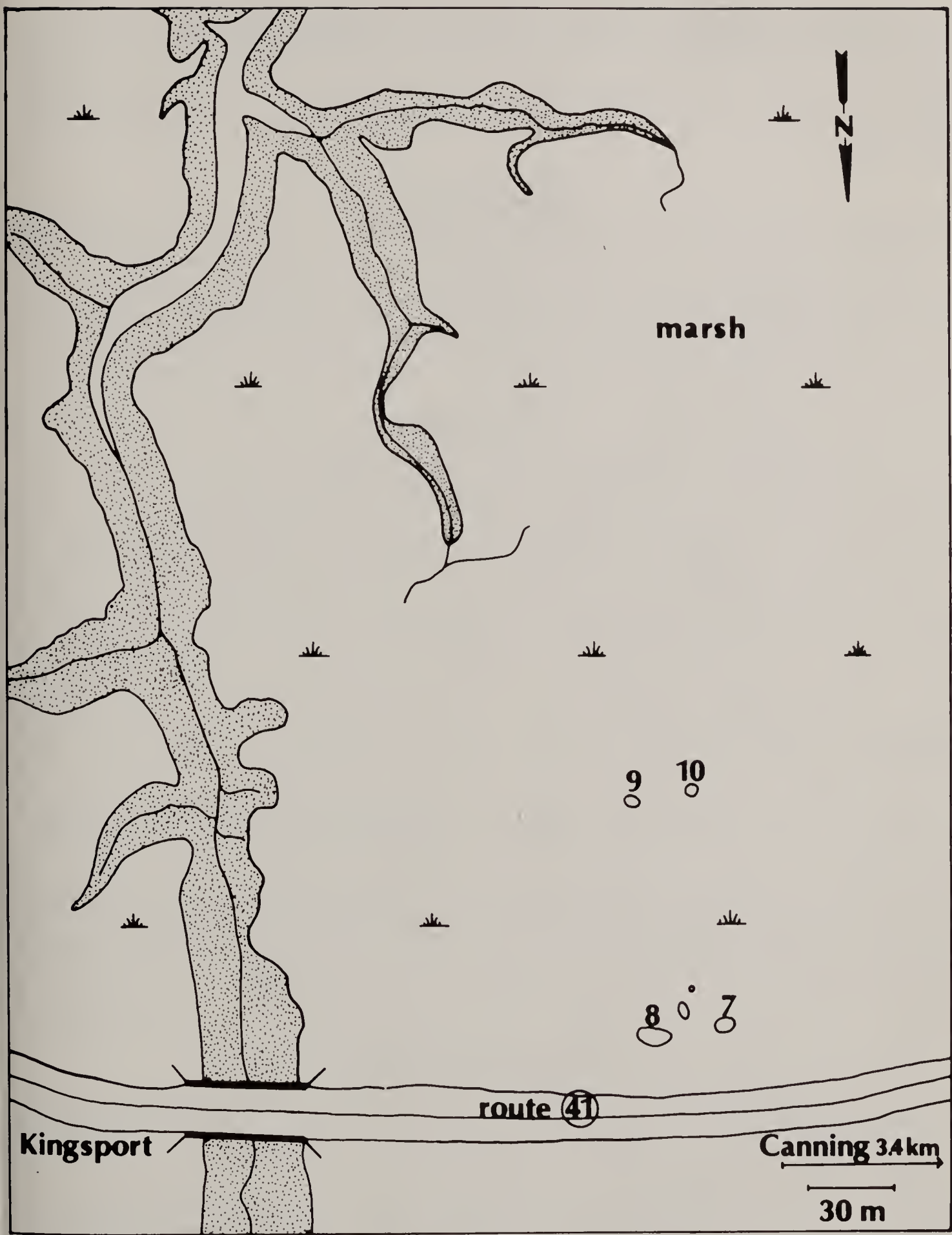


Fig 20 Study area C, location of pools 7-10; prepared from aerial photographs.

Acknowledgements

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THE LIFE HISTORY OF *COILODESME BULLIGERA* STRÖMF. (PHAEOPHYTA, DICTYOSIPHONALES)*

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Coilodesme bulligera from the Bay of Fundy was studied in culture. Swarmers from unilocular sporangia give rise to two types of thalli, microthalli with plurilocular sporangia and macrothalli with embedded, unilocular sporangia. The development of these 2 types of thalli was related to photoperiod at a temperature of around 5°C.

Introduction

Although the morphology and anatomy of *Coilodesme* has been studied in detail by Kuckuck (1929), the taxonomic position of this genus and the validity of the family Coilodesmaceae are still in dispute (Wynne 1969; 1972). In the North Atlantic, there is a single species *C. bulligera* which is considered a cold-water species, being recorded from Greenland (Rosenvinge 1893; 1898), Alaska (Wynne 1972), Labrador (Wilce 1959), and the west coast of Iceland (Kuckuck 1929). Along the northeastern coast of North America, Nova Scotia is probably the southern limit of distribution of this species (Edelstein & McLachlan 1967). In the Bay of Fundy (Digby Neck), isolated plants occur during spring and early summer in the intertidal zone epiphytic on *Ralfsia fungiformis* (Wilson et al. 1979), disappearing by midsummer. Only embedded unilocular sporangia have been found in the elongate, saccate macrothalli which erode after spore release (Kuckuck 1929).

Some species of Dictyosiphonales in culture have been shown to have a heteromorphic life history, plurilocular sporangia being formed on ephemeral microthalli (Wynne & Loiseaux 1976). In a recent study Wynne (1972) reported on the life history of 3 species of *Coilodesme* from the Pacific coast of North America; *C. bulligera* from Amchitka Island, Alaska had a 'direct' type of life history. In the present instance we are reporting on the development in culture of this species from the Bay of Fundy.

Material and Methods

Culture conditions, techniques (Chen et al. 1969), and medium (McLachlan 1973) were as previously described. Mature plants (Fig 1) were collected at Gulliver Cove and Tommy Beach, Digby Co., N.S. respectively in April 1968 and 1975. Unialgal cultures were established by procedures similar to those reported elsewhere (Edelstein et al. 1970). Incubation conditions were 5°C at 2 light periods, 16:8 h and 8:16 h (L:D); irradiance was 20 $\mu\text{E m}^{-2} \text{s}^{-1}$ provided by 40-W, cool-white fluorescent lamps. During the initial stages when the cultures were being established, GeO_2 was added (5 mg l⁻¹) to the medium which was changed weekly.

* Issued as NRCC No. 17531

** Deceased

Results

Development of the Macrothalli

Swarmers from unilocular sporangia (Fig 2), embedded in saccate thalli, developed into filamentous germlings (Fig 3) 2 to 3 days after release. About 2 weeks later, those germlings assumed various morphologies, probably representing different developmental stages. Two noticeable types of development were distinguished: one was branched filaments (Fig 4); the second type was loosely attached discs (Fig 5) with short cells. Within 2 months the majority of the filamentous thalli had formed small, globular to irregular parenchymatous bodies (Fig 6). Microscopic examination revealed the manner of differentiation of these bodies. Cells of the primary filament cut off lateral clusters of colorless, large, reniform cells (Fig 7) which subsequently formed the medulla of the macrothallus. Rapid cell-division and growth of the primary filaments gave rise to the pigmented cortical cells (Fig 8) resulting in spherical to irregularly shaped bodies with long, branched filamentous extensions. Similar differentiation occurred in the discoid germlings. Large reniform cells formed from the lower portion of the disc, lifting it up from the substratum. Rapid growth of the surface cells (i.e. cortical cells) resulted in a cup-shaped structure which finally became spherical, this being generally devoid of long, filamentous projections. After more than 2 months, when the spherical bodies reached a size of about 1 mm in diameter, erect fronds started to proliferate from it, forming clusters of saccate macrothalli of different lengths and shapes. Only a few of these macrothalli continued growth, and after 6 months hollow, clavate fronds characteristic of *Coilodesme* (Fig 9) were obtained in cultures under a long (16:8 h) light period at 5°C. Often fronds of the macrothalli aborted, the cortical layer failing to differentiate or else developing in patches over the medullary cells. In both cases, however, normal embedded unilocular sporangia (Fig 10) were formed, and after a further 2 months swarmers were released.

Under a short light period (8:16 h), development of erect macrothalli was poor or failed to occur, and the basal, spherical bodies became dark and necrotic. The structure of these spherical dark bodies was identical to that of the macrothallus, and they too developed normal unilocular sporangia, releasing swarmers and germinating in the same manner as ones from field-collected plants. Although we have not quantified the number of erect macrothalli under different photoregimes, our observations indicate that cultures kept under a long light period (16:8 h) developed many more erect macrothalli than those maintained at 8:16 h. In general agitation of the medium stimulated growth of macrothalli which usually attained a length of up to 2 cm when growth ceased and unilocular sporangia developed.

Development of the Microthalli

Under both long and short light periods, some filamentous germlings did not differentiate into spherical bodies. Instead, these filamentous clusters became darker and assumed a fuzzy appearance caused by densely-packed uniseriate, plurilocular sporangia (Fig 11). Unlike the spherical bodies of macrothalli, these clusters were composed of numerous branched filaments; we refer to these as microthalli (Christensen 1962). It, therefore, became important to study separately the progenies of both unilocular and plurilocular sporangia. Cultures were established using as inoculum complete microthalli clusters with plurilocular sporangia, and fragments of microthalli with unilocular sporangia. After 2 to 3 months of incubation, it became clear that progenies of spores from the 2 types of sporangia developed similarly, each giving rise to a mixture of new macro- and microthalli. In addition

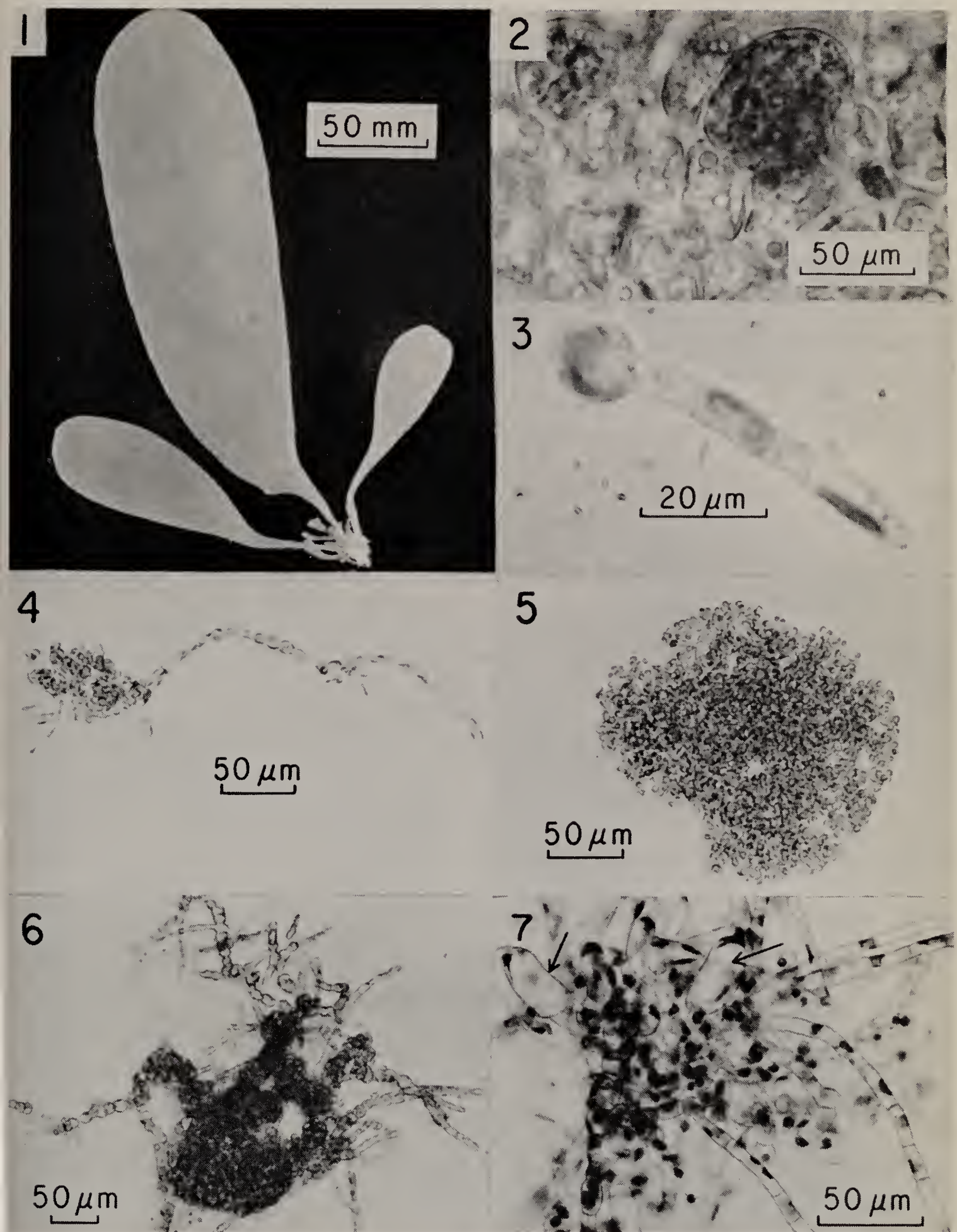
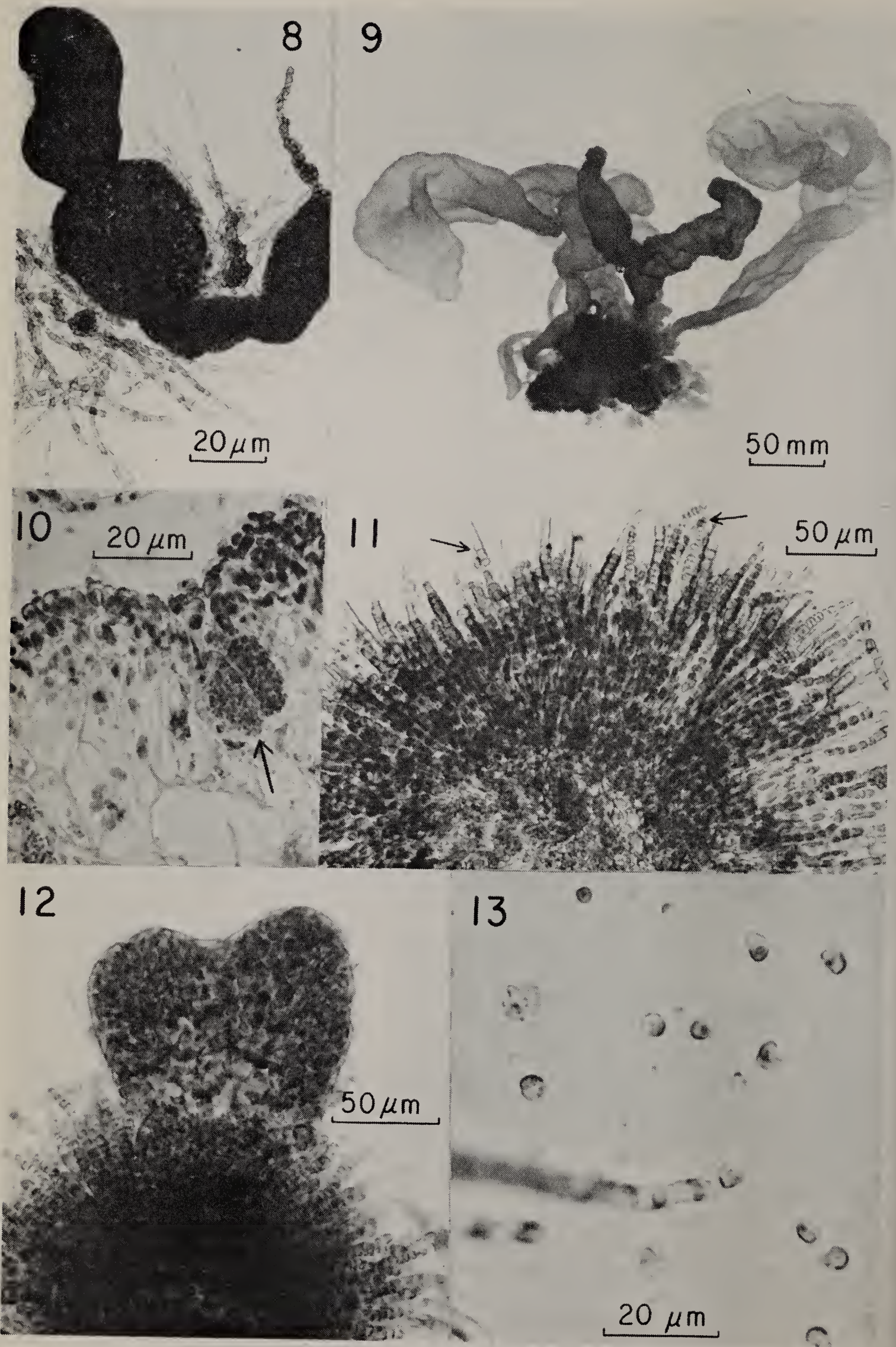


Fig. 1. Field-collected mature plant
 Fig 2. Portion of macrothallus with unilocular sporangia
 Fig 3. 2 to 3-day germling from unilocular sporangium
 Fig 4. Filamentous germling
 Fig 5. Discoid germling
 Fig 6. 2-month germling with irregular parenchymatous bodies
 Fig 7. Initiation of medullary cells (arrows) from filamentous cells



microthalli with plurilocular sporangia also issued erect macrothalli (Fig 12). Unlike microthalli of many phaeophyceae species (Wanders et al. 1972), the microthalli of *Coilodesme* did not produce successive generations without recycling the macrothallus. No fusion was noted between swimmers of either uni- or plurilocular sporangia despite repeated observations. However, resting swimmers of plurilocular sporangia (Fig 13) often increased greatly in size and acquired a thick wall, indicating possible zygote formation.

Discussion

In our culture the life history of *C. bulligera*, unlike that of *C. californica*, involved both macro- and microthalli phases. This contrasts with *C. bulligera* from the north-eastern Pacific in which macrothalli directly produced macrothalli (Wynne 1972). A similar ambiguity in the life histories of a species of brown algae is well documented elsewhere (Clayton 1979). Possibly different populations of a species may exhibit distinct life histories under genetic control rather than being controlled by abiotic factors (Nygren 1975).

Alternatively it can be suggested that apomeiosis occurs in unilocular sporangia based on observations 1) that unilocular and plurilocular sporangia were produced on both macro- and microthalli; 2) that macrothalli can originate directly from microthalli; and 3) that there was no fusion observed between swimmers. However, it is then difficult to account for 2 morphologically distinctive phases, each with a specific reproductive structure. Cytological observations would be useful in attempting to resolve this problem. Nevertheless, amongst species of brown algae, such as *Ralfsia* (Edelstein et al. 1970) and *Isthmoplea* (Edelstein et al. 1971), plurilocular and unilocular sporangia are formed only on microthalli and erect macrothalli respectively. Possibly, formation of plurilocular and unilocular sporangia in different morphological stages of the same species may be determined by temperature and/or photoperiod (Clayton 1979) reflecting similar changes in nature.

The macrothallus of *C. bulligera* from the Bay of Fundy is a spring annual, and in culture it was formed at low temperature and a long light period paralleling conditions in the field. A short light period, also at a low temperature, appeared to favor development of the microthallus; thus we should expect to find this morphological phase in the field during winter.

Acknowledgement

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Fig 8. Mass of pigmented cortical cells with filamentous extensions of the thallus

Fig 9. Mature saccate macrothallus from culture

Fig 10. Portion of saccate macrothallus with embedded unilocular sporangia (arrow)

Fig 11. Densely filamentous microthalli with plurilocular sporangia (arrows)

Fig 12. Erect macrothallus formed from microthalloid cluster

Fig 13. Resting swimmers from plurilocular sporangia

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TAXONOMIC SURVEY OF BENTHIC FAUNA IN ESTUARINE SALTMARSH POOLS, MINAS BASIN, BAY OF FUNDY

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Ten pools situated in 5 estuarine salt marshes of western Minas Basin were surveyed for benthic fauna from 1975 to 1977. Eleven phyla, comprising 56 taxa, were identified. Twenty-five new records for the pools, of which 20 are unpublished records for Minas Basin and 18 new for Bay of Fundy, included representatives from Homalorhagae, Dinophilidae, Cuthonidae, Phyllodocidae, and Spionidae. In abundance, nematodes outranked other taxa. The other dominant taxa were copepods, oligochaetes, *Hydrobia totteni*, and *Nematostella vectensis*. There was faunal variation between areas flooded frequently and those flooded only by high spring tides, and between one estuary and another. Generally, both diversity and density showed a decline during winter and early spring.

Introduction

Minas Basin is recognized as an exceptional area geologically (Goldthwait 1924; Johnson 1925) and hydrologically (Garrett 1977) but has only recently gained recognition as an equally exceptional area bionomically (Bousfield & Leim 1960; Petersen & Petersen 1977; Thomas 1977). The peculiar combination of physical characteristics within the basin provides an environment for biota which is both unique and diverse.

Petersen and Petersen (1977) and Thomas (1977) provide comprehensive accounts of published work to date on the biota of the benthic and intertidal zones of the Minas Basin and other areas of the Bay of Fundy and recommend that this work be greatly expanded, especially since the Petersens' survey revealed hydroids and polychaetes new to science. Trevors and Fuller (1977) also conducted an intensive survey of intertidal macrobenthos in Minas Basin. However, apart from species-specific studies (Bailey & Bleakney 1967; Bleakney & Bailey 1967; Frank 1974; Frank & Bleakney 1976; 1978; Norenburg 1976; Graves et al. 1979) little has been done on the general fauna of the Minas Basin salt marshes, especially the marsh pools. Until 1975, only 2 pools, among the several hundred present in the southern bight of the Minas Basin, had been investigated (K.H. Bailey unpubl).

Preliminary evidence indicated that local marsh pools are peculiarly stressed systems whose benthic communities exhibit not only low diversity and high density, but also both local and regional variation. Primarily this study set out to define the basic fauna of the benthos, to estimate their relative abundance, and to indicate something of their seasonal and regional distribution. Field sampling began in July, 1975, and ended in August, 1977 (Table I).

Description of the study area

Figure 1 is a map of the study areas in Minas Basin, which include estuarine marshes of 2 creeks, Pereau and Habitant, and 3 rivers, Canard, Cornwallis, and Gaspereau. Ganong (1903), Chapman (1960), and MacInnis (1976) have described the local marsh flora.

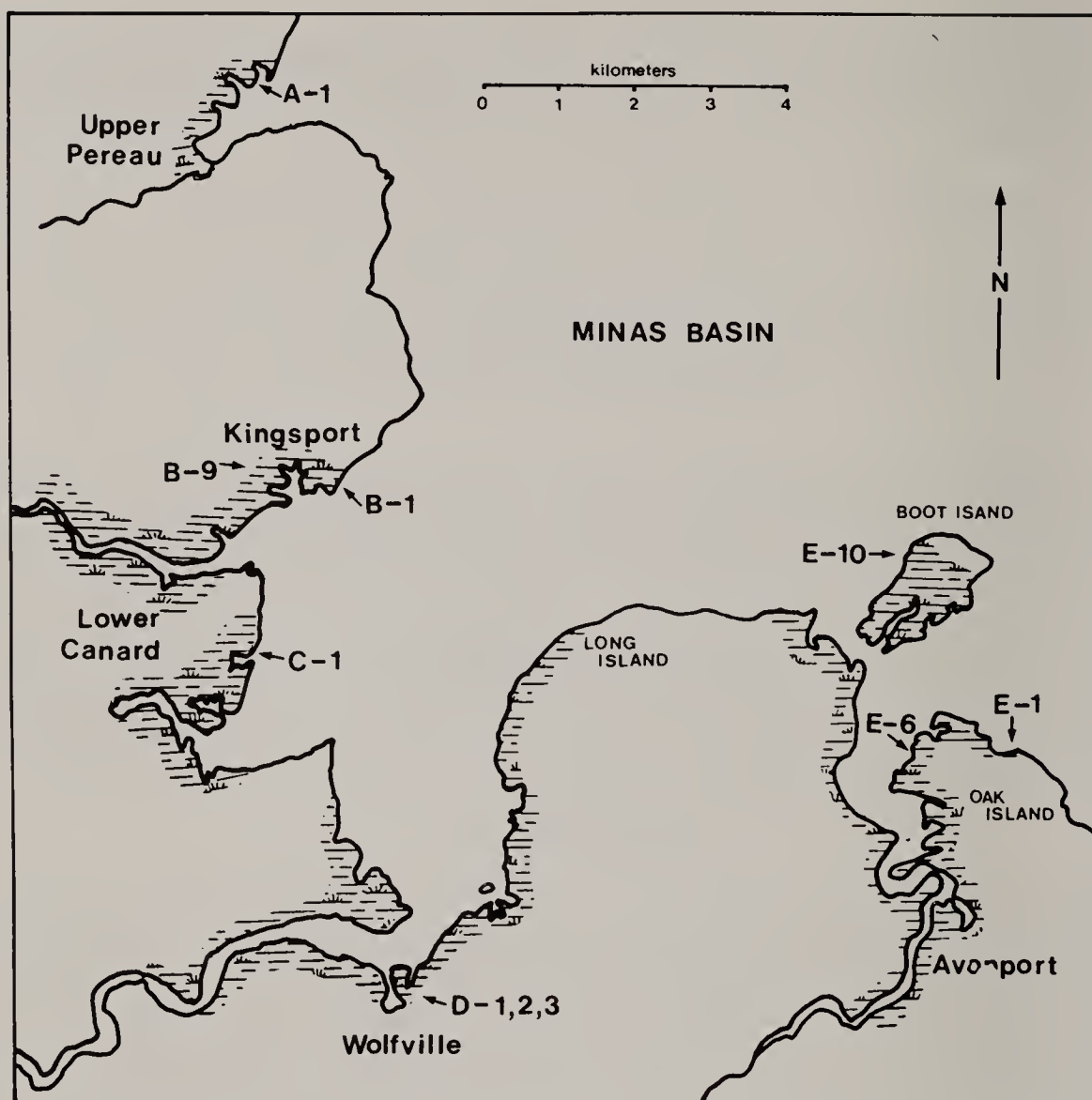


Fig 1 Study pool locations in southwestern Minas Basin, Kings Co., N.S.

Color aerial photographs (Maritime Resource Management Services, Amherst) were used to estimate the number of pools in each estuary and to choose arbitrarily pools for investigation. The majority of pools were uniformly oval; some were oblong or even rectangular. Most were small, 6 m^2 to 12 m^2 , and most had perpendicular sides, sometimes undercut and overhung with sod; the bottoms of fine sand or silt were overlain with fine detritus. Water depth did not often exceed 35 cm. With one exception, E-6, the pools sampled were on high marsh and were inundated only by spring tides or high neap tides. E-6 was much deeper than the rest with a narrow drainage ditch permitting water to enter at each tide (Table II). Evaporation and rain caused fluctuations in pool salinities; extremes of 20.5‰ to 39.3‰ and 22.6‰ to 39‰ have been reported (Table X). During the 3 summers of observation the water in no pool evaporated entirely.

The denser vegetation surrounding the pools is dominated by *Spartina patens* at higher marsh levels and by *S. alterniflora* at lower levels subject to more frequent flooding. Intermingling both are *Distichlis spicata* and *Limonium nashii*. Areas of sparse vegetation are colonized by *Salicornia europaea* and *Sueda maritima*. Within the pools *S. alterniflora* is an emergent, and during the observation period, colonizing D-1 almost entirely, trapping the sediment load of the incoming tide, and gradually reducing the pool's area. Observations have not been made over a long

Table I. Sampling periods for saltmarsh pools, 1975-1977 in Minas Basin. River estuaries are: A - Pereau, B - Habitant, C - Canard, D - Cornwallis, and E - Gaspereau. The aggregate of individual specimens removed from benthic grab samples at each pool is indicated.

Estuary	Pool	Sampling period	Total organisms counted
A	A-1	1976, Feb., May, 1977, April	6,349
B	B-1	1976, Feb; 1977, July	2,505
	B-9	1976, Nov.	7,056
C	C-1	1976, May; 1977, Aug.	2,184
D	D-1	1975, July; 1976, Jan., July; 1977, Mar.	14,474
	D-2	1976, Jan.	965
	D-3	1975, Sept. (algal sample)	203
E	E-1	1976, Feb., Aug.	3,748
	E-2	1976, May; 1977, June	6,715
	E-10	1976, June; 1977, June	12,036

Table II. Physical aspects of marsh pools sampled in Minas Basin. (agri, close to agricultural run-off; hneap, high neap; remote, at least 1 km from habitations; swg, close to urban sewage outlet).

Pool	Location	Bottom	Depth (cm)	Tidal flooding	Area (m ²)
A-1	agri	sand	20	hneap	195
B-1	agri	mud	20	spring	71
B-9	agri	mud	20	spring	105
C-1	agri	mud	20	spring	103
D-1	swg	mud	20	spring	12
D-2	swg	mud	15	spring	3
D-3	swg	mud	15	spring	14
E-1	agri	mud	35	spring	15
E-6	agri	mud	100	daily	229
E-10	remote	mud	25	spring	403

enough period to determine whether or not this process results in the obliteration of the pool, but according to Dr. Kenneth Mann (in litt.), *S. alterniflora* cannot survive as an emergent longer than about 3 years. Other pool flora include *Ruppia maritima*, and algae such as species of *Enteromorpha*, *Cladophora*, *Chaetomorpha*, and *Rhizoclonium* which vary in abundance from pool to pool.

Pereau Creek Salt Marshes (W. 64°24', N. 45°12')

Pereau Creek salt marshes comprise 16 ha (Hilchey & Cann 1953), most of which lie on the north bank of the estuary. Across this bank flow 4 widely-spaced brooks draining the south slope of North Mountain. About 17 pools are scattered on the marsh bordering the second most westerly of the 4 brooks and the largest pond, A-1, was selected for sampling (Fig 1, Table II).

Habitant Creek Salt Marshes (W. 64°23', N. 45°09')

Through deterioration of the dykes, the area east of the causeway reverted to salt marsh, most of which is located on the north bank. Six brooks, draining agricultural land, transverse the north bank, and effluent from 2 community settling ponds drains into the creek above the causeway. At least 135 pools occur from Kingsport to this causeway at the head of the estuary. About 6 pools are located on the less extensive marsh occupying the south bank, 2 of which were studied by Bailey in 1965-67 (Bailey 1967; Bleakney & Meyer 1979). On the north bank, near Kingsport, 2 widely spaced pools were chosen for sampling: B-1, the site of a more specific study of *Nematostella vectensis* by Frank (1974) and B-9, located beside a large gully which drains the farmlands north of the highway (Fig 1, Table II).

Canard River Salt Marshes (W. 64°23', N. 45°08')

East of the dyke and causeway crossing the Canard River there are 177 ha of saltmarsh (Hilchey & Cann 1953) almost equally divided between the north and south banks of the estuary. The marsh is dissected by erosion channels and there are an estimated 400 pools, about 20 lying on the south bank. C-1 was selected from a small group of pools, located in an area of agricultural run-off at the north-east extremity of the estuary (Fig 1, Table II).

Cornwallis River Salt Marshes (W. 64°22', N. 45°07')

The Cornwallis River salt marshes are the most extensive in the Minas Basin and include: (1) the salt marsh portion of the Grand Pré marsh body (Hilchey & Cann 1953) comprising 90 ha (Fuller & Woodman, in verb.). It lies to the east of the Cornwallis River and to the west of the Wickwire dykeland which was reclaimed by Maritime Marshlands Reclamation Committee in 1962 and includes Long Island marsh and the east shore of Wolfville Harbour; and (2) 468 ha of salt marsh described by Hilchey and Cann (1953) as lying at the mouth of the Cornwallis River, west of Wolfville and south of Starrs Point, an area known as Sutton's marsh. About 57 pools lie in the Cornwallis salt marsh: 33 on Long Island, 21 on the marshes bordering Wolfville Harbour and 3 on the Sutton marsh south of Starrs Point. Study pools D-1, D-2, and D-3 were selected on the east side of Wolfville Harbour immediately north of the Dominion Atlantic Railway. D-1 and D-2 lay within 100 m southeast of the raw effluent of the town's main trunk sewer (Fig 1, Table II). This outflow was terminated by the installation of a sewage treatment plant in 1978.

Gaspereau River Salt Marshes (W. 64°16', N. 45°06', + 08')

Gaspereau River salt marshes comprise about 350 ha (Hilchey & Cann 1953) in-

cluding Boot Island marsh and extending from Oak Island, west of Avonport Beach, along the east and west banks at the mouth of the Gaspereau River as far as the eastern end of Long Island. About 20 pools are scattered along the east bank of the river from Oak Island to the railway bridge. On the west bank, from the 101 Highway bridge to Long Island, there are about 27 pools, with another estimated 70 pools on Boot Island marsh. Study pools E-1 and E-6 are located on Oak Island and E-10 on Boot Island (Fig 1, Table II). The elevation of E-1 protects it from direct run-off originating in the surrounding agricultural lands and nearby habitation. In contrast, E-6 is readily contaminated by agricultural run-off from the ditch to which it is connected. The island location of E-10 isolates it from direct influence of agricultural lands, but its proximity to an extensive gull nesting colony could be equally significant in terms of both nutrients and pollutants.

Materials and Methods

The initial strategy had been to sample randomly selected pools, 1 from each of the 5 estuarine marshes, monthly for 2 years. However, the scrutiny to which each sample was subjected sometimes occupied as much as 6 weeks. This resulted in an irregular sampling schedule for, at most, only 1 pool per marsh per month could be processed (Table I). Severe winter conditions also required altering the sampling schedules.

Random samples were taken, by means of a plexiglass grab (Frank 1974) which was pressed into the substrate to a depth of 1 cm; the inside dimensions were 15 cm x 15 cm with a total volume collected of about 225 ml. Since the pools were small, a single sample was collected from a given pool at any one time to avoid disruption.

In summer, washing and screening of the samples were done at nearby pools. In winter, usually screening was done in the laboratory using water from the pools. Five grades (mesh sizes 3.360 mm, 1.558 mm, 0.602 mm, 0.351 mm, 0.223 mm, and 0.093 mm) of rigid nylon screen (NITEX) were used successively. Those organisms passing the 0.223 screening constituted such large numbers of nematodes and copepods that, for reasons of expediency, they were not included in the survey.

Analysis of each 225 ml field sample was done by transferring sub-samples of about 0.3 ml to the bottom of a 60 mm x 15 mm plastic petri dish, the top of which was modified as a counting grid. Each 12 mm square grid unit was exactly circumscribed by the 12x field of a Wild M5 binocular microscope, and the sub-samples were of such small density that every particle was discernible. A series of sub-samples was prepared, allowed to settle, placed upon the counting grid, and tabulated as absolute numbers for each taxon for each pool (Appendix I).

Once assigned taxonomic rank, individuals were stored at 5°C. Before further processing, representative specimens were photographed (Bleakney 1970). Photomicrographs were taken using a Pentax KX fitted to a Wild M5 binocular microscope.

Most organisms were readily identified with the aid of available literature; obscure taxa were sent to appropriate specialists. The following persons were most helpful: Dr. Louise Bush, platyhelminths; Dr. M.J. Dadswell, oligochaetes; Dr. R.P. Higgins, kinorhynchs; Mr. Jon Norenburg, nemertines; Dr. Marion H. Pettibone, polychaetes; and Dr. Gustavs Vilks, foraminiferans.

Results

A total of 63 benthic taxa, distributed among 11 phyla, were recorded from the 10 marsh pools (Table III). Sixty-four percent of the fauna were given specific rank,

Table III. Distribution of 63 taxa collected from Minas Basin salt marsh pools, 1975 to 1977.

	A-1	B-1	B-9	C-1	D-1	D-2	D-3ϕ	E-1	E-6	E-10	Totals	v%
Phylum Protista												
<i>Ammotium salsum</i>	*	*	*	*	*	*	*	*	*	*		
<i>Miliammina fusca</i>	*	*	*	*	*	*	*	*	*	*		
<i>Ammonia beccarii</i>	*	*	*	*	*	*	*	*	*	*		
<i>Trochammina inflata</i>	*	*	*	*	*	*	*	*	*	*		
<i>Jadammina polystoma</i>	*	*	*	*	*	*	*	*	*	*		
<i>Haplophragmoides bonplandi</i>	*	*	*	*	*	*	*	*	*	*		
<i>Criboelthidium excavatum</i>	*	*	*	*	*	*	*	*	*	*		
<i>Elphidium</i> sp	*	*	*	*	*	*	*	*	*	*		
Phylum Cnidaria												
<i>Protohydra leuckarti</i>	+		+		+				+	+	129	50
<i>Nematostella vectensis</i>	+	+	+		+	+	+	+		+	2810	80
Phylum Platyhelminthes												
<i>Neochildia fusca</i>	+								+	+	44	30
<i>Macrostomum</i> sp		+	+								2	20
D-6.11.76			+		+						3	20
Ty-28.3.77					+						1	10
E-28.3.77					+						1	10
S-28.3.77					+						1	10
<i>Otomesostoma</i> sp				+							175	10
<i>Monocelis durhami</i>				+							64	60
Phylum Nemertea	+	+	+						+	+		
<i>Prostomatella obscura</i>	+	+		+	+						31	50
<i>Lineus viridis</i>	+	+			+	+					18	20

	A-1	B-1	B-9	C-1	D-1	D-2	D-3ϕ	E-1	E-6	E-10	Totals	v%
Phylum Rotifera												
Unidentified	*	*	*	*	*	*	*	*	*	*		100
Phylum Kinorhyncha												
Pycnophyes 1016.4									+		36	10
Pycnophyes 1016.6	+										7	10
Phylum Nematoda												
Unidentified	*	*	*	*	*	*	*	*	*	*		100
Phylum Bryozoa												
Bowerbankia gracilis	+		+		+				+		18	40
Phylum Mollusca												
Littorina littorea	+	+				+			+		8	40
Littorina saxatilis	+	+					+	+	+	+	6	60
Hydrobia totteni	+	+	+	+	+	+	+	+	+	+	5778	100
Ilyanassa obsoleta	*	*	*	*	*	*	*	*	*	*		100
Stiliger fuscatus		+									2	10
Alderia modesta				+	+						40	10
Elysia chlorotica	+			+	+						6	20
Physa sp							+				1	10
Mytilus edulis	+								+		2	20
Geukensia demissa									+		2	10
Hiatella striata										+	1	10
Gemma gemma	+								+		38	20
Mya arenaria									+		1	10
Phylum Annelida												
Dinophilus sp				+	+		+				8	30
Eteone heteropoda	+	+	+		+	+			+	+	19	70
Eteone longa	+								+	+	15	30
Nereis diversicolor		+		+	+				+	+	85	50
Heteromastis filiformis				+	+				+	+	93	30
Streblospio benedicti	+			+	+				+	+	51	40

	A-1	B-1	B-9	C-1	D-1	D-2	D-3♂	E-1	E-6	E-10	Totals	v%
<i>Pygospio elegans</i>	+							+	+	+	10	40
<i>Polydora ligni</i>	+		+		+	+				+	235	50
<i>Scoloplos fragilis</i>				+	+				+		33	20
<i>Fabricia sabella</i>	+	+	+								101	30
<i>Manayunkia aestuarina</i>	+		+						+	+	49	40
<i>Oligochaeta</i>	+		+	+	+		*	+	+	+	3006	90
<i>Pelosclex benedeni</i>	*				*		*		*	*		40
<i>Isochaeta hamata</i>	*		*		*					*		20
<i>Tubifex pseudogaster</i>												30
Phylum Arthropoda												
Acarina	+	+	+	+	+	+	*	+	+	+	426	100
Ostracoda	+	+		+	+			+	+	+	880	70
Copepoda	+	+	+	+	+	*	+	+	+	+	6264	100
<i>Jaera marina</i>	+										4	10
<i>Corophium volutator</i>	+	+		+	+				+	+	953	60
Gammarus						+			+	+	142	70
<i>mucronatus</i>	+	+	+	+	+	+					24	20
<i>Orchestia grillus</i>				+	+						1	10
† <i>Carcinus maenus</i>				+	+		+				2	10
Corixidae						+		+	+		452	80
Chironomidae	+	+	+	+	+		+				1	10
Hydrophilidae												
Total taxa	35	22	21	17	33	14	16	13	31	27		
Percent total collected taxa	56	35	32	25	51	22	25	21	49	43		

+ = present and quantified; * = present but not quantified; † = observed but not collected; ♂ = pool from which was collected only an algal sample; v% = percent abundance among all pools sampled.

with an additional 14% given generic rank. Of the remaining 22%, 16% were assigned ranks above suborder and 6% assigned to families. Because of the difficulties, of isolation and identification, turbellarians (*Monocelis* excepted), rotifers, nematodes, acarinids, ostracods, and copepods, were not further classified.

Table IV lists all species known to occur in these pools based on material from this survey and from other collections at Acadia University dating back to 1965. The sources of these additional records are indicated in the table and bring the total fauna to 73 taxa.

Table IV. Checklist of fauna collected 1965-77 from saltmarsh pools of Minas Basin. These include benthic, epibenthic, and epiphytic species. Taxa recorded previous to the 1975-77 survey are indicated by author and are included here for completeness as most of those records were unpublished. Asterisks indicate organisms which are illustrated by line-drawings in Bromley (1978).

Fauna - 76 taxa	Storage jar Id. number	Records previous to 1975
Phylum PROTISTA		
Order Foraminiferida		
<i>Ammotium salsum</i> (Cushman and Brönniman 1948)	1007.9	
<i>Miliammina fusca</i> (Brady 1870)	1007.1	
<i>Ammonia beccarii</i> (Linnaeus 1758)	1007.8	
<i>Trochammina inflata</i> (Montagu 1808)	1007.7	
<i>Jadammina polystoma</i> (Bartenstein and Brand 1938)	1007.16	
<i>Haplophragmoides bonplandi</i> (Todd and Brönniman 1957)	1007.11	
<i>Criboelthidium excavatum</i> (Terquem 1876)	1007.10	
<i>Elphidium</i> sp	?	
Class Ciliatea		
<i>Lachrymaria</i> sp		
<i>Zoothamnium</i> sp		
<i>Semifolliculina gigantea</i> Dons 1913		Bailey 1967
Phylum CNIDARIA		
Class Hydrozoa		
Family Hydridae		
<i>Protohydra (leuckarti</i> Greeff 1870) sp	1008.1	Petersen 1970
Class Anthozoa		
Family Edwardsiidae		
<i>Nematostella vectensis</i> Stephenson 1935	1008.3	Bailey & Bleakney 1966
Phylum PLATYHELMINTHES		
Class Turbellaria		
Order Acoela		
Family Proporidae		
<i>Neochildia fusca</i> Bush 1975	1003.11	

Fauna - 76 taxa	Storage jar Id. number	Records previous to 1975
Order Rhabdocoela		
Family Microstomidae		
* <i>Macrostomum</i> sp		
Suborder Lecithophora		
Division Dalyellioida		
*D-6.11.76	1003.10	
Division Typhloplanoida		
*Ty-28.3.77	1003.13	
Division Kalyptrorhynchia		
Subdivision Eukalyptrorhynchia		
*E-28.3.77		
Subdivision Schizorhynchia		
*S-28.3.77		
Order Alloeocoela		
Family Otomesostomidae		
<i>Otomesostoma</i> sp	1003.18	
Family Monocelis		
<i>Monocelis durhami</i> Hyman 1964	1003.8	
Phylum NEMERTEA		
Class Enopla		
Family Tetrascemmatidae		
<i>Prostomatella obscura</i> (Schultz 1851)		Norenburg 1976
<i>Amphiporus angulatus</i> (Fabricius 1774)		Norenburg 1976
Class Anopla		
Family Lineidae		
<i>Lineus viridis</i> Johnston 1865		Norenburg 1976
Phylum ROTIFERA		
Phylum KINORHYNCHA		
Family Homalorhagae		
<i>Pycnophyes</i> 1016.4	1016.4	
<i>Pycnophyes</i> 1016.6	1016.6	
Phylum NEMATODA	1016.1 to 2	
Phylum BRYOZOA		
Class Gymnolaemata		

Fauna - 76 taxa	Storage jar Id. number	Records previous to 1975
Family Vesicularidae		
<i>Bowerbankia gracilis</i> Leidy 1855		Bailey 1967
Phylum MOLLUSCA		
Class Gastropoda		
<i>Littorina littorea</i> (Linnaeus 1758)	1004.6	Bailey 1967
<i>Littorina saxatilis</i> (Olivi 1792)	1004.5	Bailey 1967
<i>Hydrobia totteni</i> (Morrison 1954)	1004.8	Bousfield 1960
<i>Ilyanassa obsoleta</i> Say 1822	1004.10	Bailey 1967
Subclass Opisthobranchia		
Order Sacoglossa		
<i>Stiliger fuscatus</i> Gould 1870		Bleakney (unpubl.)
<i>Alderia modesta</i> Loven 1944		Bleakney & Bailey 1967
<i>Elysia chlorotica</i> Gould 1870	1004.4	Bailey & Bleakney 1967
Order Nudibranchia		
<i>Tenellia</i> sp		Bleakney (unpubl.)
Class Bivalvia		
<i>Mytilus edulis</i> Linnaeus 1758		
<i>Geukensia demissa</i> (Dillwyn 1817)	1010.2	
<i>Gemma gemma</i> Totten 1834	1010.1	Bailey 1967
<i>Hiatella striata</i> Fleury 1802		
<i>Mya arenaria</i> Linnaeus 1758		
Phylum ANNELIDA		
Class Polychaeta		
Order Archiannelida		
Family Dinophilidae		
<i>Dinophilus</i> sp	1013.9	
Family Phyllodocidae		
<i>Eteone heteropoda</i> Hartman 1957	1013.32	
<i>Eteone longa</i> (Fabricius 1780)	1013.21a	
Family Nereidae		
<i>Nereis diversicolor</i> Müller 1776	1013.23	
Family Capitellidae		
<i>Heteromastis filiformis</i> Claparède 1864	1013.10	
Family Spionidae		
<i>Streblospio benedicti</i> Webster 1879	1013.17	
<i>Pygospio elegans</i> Claparède 1863	1013.2	
<i>Polydora ligni</i> Webster 1879	1013.20	

Fauna - 76 taxa	Storage jar Id. number	Records previous to 1975
Order Ariciida		
Family Orbiniidae		
<i>Scoloplos fragilis</i> (Verrill 1873)	1013.7	
Order Sabellida		
Family Sabellidae		
<i>Fabricia sabella</i> (Ehrenberg 1837)	1013.6	
<i>Manayunkia aestuarina</i> (Bourne 1883)	1013.11	Petersen & Petersen 1977
Class Oligochaeta		
Family Tubificidae		
<i>Peloscolex benedeni</i> (Udekem 1835)	1001.11	
<i>Isochaeta hamata</i> (Moore 1905)	1001.27	
<i>Tubifex pseudogaster</i> (Dahl 1960)	1001.26	
Phylum ARTHROPODA		
Order Acarina	1002.1 to	14 Bailey 1967
Subclass Ostracoda	1006.1 to 8	
Order Ispoda		
<i>Jaera marina</i> (Fabricius 1780)	1012.1	
Order Amphipoda		
<i>Corophium volutator</i> (Pallas 1766)	1014.5	
<i>Gammarus mucronatus</i> Say 1818	1014.1	Bousfield 1960
<i>Orchestia grillus</i> Bosc 1802	1014.3	Bousfield 1960
Order Decapoda		
<i>Carcinus maenus</i> (Linnaeus 1758)	1017.1	
Class Insecta		
Order Hemiptera		
Family Corixidae	1018.2	Bousfield 1960
Order Diptera		
Family Chironomidae	1000.14	
Family Ephydriidae		
<i>Ephydra riparia</i>		Bailey 1967
Family Tabanidae		
<i>Tabanus nigrovittatus</i> (Macquart)		Bailey 1967

Fauna - 76 taxa	Storage jar Id. number	Records previous to 1975
Order Coleoptera		
Family Hydrophilidae		
<i>Enochrus hamiltoni</i> Hatch and Kincaid		Bailey 1967
Phylum CHORDATA		
Class Osteichthyes		
<i>Anguilla rostrata</i> (Le Sueur 1817)		Bailey 1967
<i>Fundulus heteroclitus</i> (Linnaeus 1766)		Bailey 1967
<i>Gasterosteus aculeatus</i> Linnaeus 1758		Bailey 1967
<i>Apeltes quadracus</i> (Mitchill 1815)		Bailey 1967
<i>Pungitius pungitius</i> (Linnaeus 1758)		Bailey 1967

Several specimens were unavoidably lost and the only records are figures. These are identified by the initial of the lowest taxonomic level plus the date collected, e.g. E-28.3.77 refers to a member of the subdivision Eukalyptorhynchia collected 28 March 1977.

Appearing in the second column opposite most specimens in Table IV is a bipartite number. The first part signifies the storage jar number and the second part the number of the vial within the jar, e.g., 1003.18 refers to a member of the Dalyelioida stored in vial 18, Jar No. 1003. All specimens from this 1975 to 1977 study have been labelled in this manner for later reexamination by specialists and are stored in Acadia University's Museum.

Certain species and groups merit further comment relative to new observations on habits, density, feeding, or taxonomic difficulties, and are treated here prior to analysis of the numerical data.

Phylum Protista

Although it was decided to exclude protists from this study, foraminiferans were so abundant and so easily isolated that some species were recorded but not quantified. Several species of calcareous Rotaliidae were destroyed in improperly buffered preservatives. Seven other species were confirmed by Vilks (in litt.) and all have been reported to occur commonly in marshes (Murray 1971; Scott 1978).

Phylum Cnidaria

Class Hydrozoa

This appears to be the first record of *Protohydra leuckarti* Greef 1870 from the Bay of Fundy region and both pink and colorless specimens were observed feeding on nematodes and dividing by transfission.

Class Anthozoa

Nematostella vectensis Stephenson 1935 was intensively investigated in Minas Basin pools (Frank & Bleakney 1976) and was one of the most widely distributed and abundant taxa.

Phylum Platyhelminthes

Five species could not be identified even to genus, but detailed notes on behavior and drawings were made (Bromley 1978).

Phylum Nemertea

Class Enopla

Prostomatella obscura (Schultz 1851) is a hoplonemertean first reported from the Baltic region. The Minas Basin populations were the first to be noted in North America and this species is the only nemertean known to complete its life cycle in salt marshes (Norenburg 1976).

Class Anopla

Lineus viridis (Fabricius) Johnston 1865 was said by Verrill (1888) to be "abundant at all locations about the Bay of Fundy." No records for this area have since appeared in the literature, but in 1976 Norenburg reported its rediscovery and common occurrence in several Minas Basin saltmarsh pools.

Phylum Rotifera

Representatives of this phylum were present in all the pools but in small numbers.

Phylum Kinorhyncha

Family Homalorhagae

Species of *Pycnophyes* have been dredged from the surface of sandy muds from depths of 1 to 40 m (Southern 1914; Blake 1930; Wieser 1960; McIntyre 1964; Higgins 1964; 1966), but none except *Echinoderes coulli* (Higgins 1977) appears to have been gathered from an estuarine salt marsh. Higgins (in litt.) confirmed the generic position of Minas Basin Pycnophyidae, and inferred that the single specimen (*Pycnophyes* 1016.4) which he examined from E-6 was a new species. Those from A-1 (*Pycnophyes* 1016.6) differ, appearing to be another species of *Pycnophyes*, possibly *frequens*.

Phylum Nematoda

No attempt was made to identify members of this difficult taxon, nor to estimate the myriads which escaped the finest screens. Numerically nematodes dominate the meiofauna of the pools and the quantities recorded herein are probably low by several orders of magnitude.

Phylum Bryozoa

Family Vesicularidae

Although *Bowerbankia gracilis* Leidy 1855 (+ *caudata* Osburn 1919) is distributed from Greenland to Brasil on both American coasts (Maturro 1956) and is common on a number of seaweeds in shallow water (Rogick & Croasdale 1949), it was not included in the extensive collection of Bryozoa reported by Powell and Crowell (1967) from Minas Basin. Bailey (1967) first reported *B. gracilis* in saltmarsh pools, and it was found in 1976 associated with species of *Vaucheria*, *Ruppia*, and *Spartina* detritus. Of those collected in 1976, the zooecia varied in their possession of a caudate process.

Phylum Mollusca

Family Hydrobiidae

Hydrobia totteni Morrison 1954 was reported by Bousfield and Leim (1960) for the Minas Basin, but Smith (1964), apparently avoiding assigning specific rank, asserted that "several species of this difficult but widespread genus may occur." From Minas Basin collections on 15 February 1976, morphological variants, designated A and B (Table V) were evident in samples from pool E-1.

Table V. Polymorphism in *Hydrobia* from Minas Basin saltmarsh pool E-1, February 15, 1976.

Structure	Morph A	Morph B
Shell	truncated spire (usually)	pointed spire
Shell color	grey-green	golden
Body color	black	grey-brown
Growth lines	pearl-grey, distinct	indistinct
Texture	rough	smooth
Aperture	proportionally smaller than B	proportionally larger than A
Operculum	irridescent black; distinct spiralling	opaque golden; indistinct spiralling
Head	long; velvety-black pigmentation	shorter; lighter pigment than A
Tentacles	tipped with black	not so

In a holding jar, containing 53 A-morphs and 64 B-morphs, all the A's had crawled to the water surface. The B's had a pink cast to their shells, imparted by an apparent film of epibionts. Further differences are summarized in Table V. The fact that 3 species of *Hydrobia* in Britain can be readily separated on the basis of tentacular pigmentation (Bishop 1976) supports our hypothesis that there is more than 1 species of *Hydrobia* in Minas Basin.

Order Sacoglossa

On 21 October, 1970, Bleakney discovered *Stiliger fuscatus* Gould 1870 in a pool on Habitant Marsh, following which a number of collections have been made from other Minas Basin pools. Specimens from B-1 agree with the description of Marcus (1958), and possess an unnotched anterior margin, which disagrees with the illustration of *S. fuscatus* (after Gould 1870) presented in Abbott (1974). Gascoigne (1976; 1978) used specimens from Minas Basin as material for his anatomical studies.

The saltmarsh sacoglossan, *Alderia modesta* Loven 1844 occurs in Europe, and along the east and west coasts of North America (Abbott 1974). Forty specimens were extracted from the 28 January sample at Pool D-1. They are winter residents in some pools, often beneath thick ice, and move onto the marsh in summer, feeding on *Vaucheria* mats.

Elysis chlorotica Gould 1870 was reported for the first time in Canada by Bailey and Bleakney (1967). Their specimens, from Minas Basin pools, were usually found on *Cladophorales* or on the marsh surface on *Vaucheria* mats, from which they ex-

tract and incorporate functional chloroplasts into their gut cells (Graves et al. 1979). Specimens collected from D-1, January 1976, were 30 mm long, and clung to the undersurface of ice, 15 cm thick. Those collected from A-1 in May 1976 were less than 1 mm long, and were crawling over filaments of *Cladophora*.

Order Nudibranchia

Four specimens of *Tenellia* sp, previously recognized as *Embletonia* (Roginskaya 1970), were collected by Bleakney 18 July 1973, from Canard Estuary, in pools situated southwest of C-1 on the low marsh. A cold-water genus of the northwest Atlantic (Abbott 1974), this hydroid predator has also been found in the *Sabellaria vulgaris* zone at low water off Kingsport wharf in Minas Basin.

Class Bivalvia

The soft sand of pool A-1 (Table II) is an unexpected habitat for *Mytilus edulis* Linnaeus 1778, and the presence of a 60 mm specimen in A-1 in February suggests winter-storm transport.

The ribbed mussel, *Geukensia demissa* (Dillwyn 1817), an important inhabitant of many tidal marshes (Gould 1870; Teal & Teal 1969; Morris 1973; Abbott 1974) is rare in Minas Basin. Although Bousfield and Leim (1960) do not include *G. demissa*, Bousfield (1964) later does so. They were found only at E-6 and in several neighboring pools, where they formed dense colonies. The colony in E-6 lay half-buried in a bed of *Spartina alterniflora* and was exposed between tides. Colonies in neighboring pools were in the bottom mud and were always submerged.

The gem clam *Gemma gemma* Totten 1834 had been reported from Canard marsh pools (Bailey 1967), but during this survey it was found only in A-1, the only pool with a sand substrate.

A single juvenile specimen of *Hiatella striata* Fleurian 1803, 5 mm long, was collected from E-10. Present in the lower Bay of Fundy (Linkletter et al. 1977), it has not been reported from Minas Basin. Although *H. striata* and *H. arctica* are almost indistinguishable as adults (Abbott 1974; Linkletter et al. 1977), the absence of radial spinose ribs in the young is diagnostic of *H. striata* (Abbott 1974). The presence of this pelycopod borer in a pool must be attributed to storm transport.

Mya arenaria Linnaeus 1758 is common in the mud flats of Minas Basin (Bousfield & Leim 1960) and the single 5 mm specimen in E-6 was probably the result of transport. There is no indication that this species is established in the pools.

Phylum Annelida

Class Polychaeta

Eteone heteropod Hartman 1951 reportedly ranges from Maine to Texas and frequents low-salinity salt ponds (Pettibone 1963). Linkletter et al. (1977) reported it in the lower Bay of Fundy, and Gratto (1977) established the first record for Minas Basin.

Pettibone (in litt.) confirmed the identify of the *Eteone longa* (Fabricius 1780), collected from A-1, E-6 and E-10. Pettibone (1963) has examined specimens from the Bay of Fundy, but this appears to be the first record for Minas Basin. *Eteone longa* has not previously been reported from brackish water. Further study might indicate whether or not it completes a life cycle within the pools, as may be the case with *E. heteropoda*. It should be noted as well that *Manayunkia aestuarina* reported first by Peterson and Peterson (1977) was collected only from A-1 and E-6, indicating a marine affinity. *Nereis diversicolor* Müller 1776 was taken from B-1, C-1, D-1, E-6, and E-10. Only 1, from D-1, 28 January 1976, was a mature adult, about 105 mm, sex unknown.

The first published Canadian record of *Pygospio elegans* Claparede 1863 was from Wedgeport, Yarmouth and Sandy Cove, N.S. (Berkeley & Berkeley 1956). *Pygospio elegans* next appeared in the checklist of Linkletter et al. (1977). This study affords the first reports for Minas Basin with specimens from A-1, E-1, E-6, and E-10. Miner (1950) describes the color patterns as yellow and white, whereas local specimens were pink and green; but Pettibone (in litt.) verified the diagnosis.

Polydora ligni Webster 1879 is an estuarine species (Hartman 1951; Blake 1969; 1971) and was collected from A-1, B-9, D-1, D-2, and E-10 in higher numbers than any other polychaete gathered during the study.

Scoloplos fragilis (Verrill 1873) ranges from the Gulf of St. Lawrence to the Gulf of Mexico, and has been dredged in shallow water muds and in estuaries (Pettibone 1963). The first record for Minas Basin was from intertidal mud flats (Gratto 1977). Marsh specimens were collected from only two pools, D-1 and E-6.

Manayunkia aestuarina found at pools A-1, B-9, E-6, and E-10, is not included in extant keys. External morphological features closely parallel those of *Fabricia sabella*, but an important diagnostic difference is the presence of simple branchial lobes. Specimens were verified by Pettibone (in litt.) and detailed notes and drawings are in Bromley (1978).

Class Oligochaeta

The oligochaeta annelids, present in all pools, comprised an immense assemblage of what appeared to be relatively few species.

Three genera could be readily separated from the rest by their distinctive external characteristics and behavioral patterns. These were identified by Dadswell (in litt.)

Table VI. Checklist of invertebrate taxa reported from United States east coast saltmarsh pools. The right hand column indicates those occurring in Minas Basin saltmarsh pools.

Fauna	Teal & Teal 1969	Nixon & Oviatt 1973	Minas Basin
<i>Nematostella</i>		+	+
<i>Euplana</i>		+	
<i>Nematodes</i>		+	+
<i>Modiolus</i>		+	+
<i>Mercenaria</i>		+	
<i>Mya</i>		+	+
<i>Scolocolepides</i>		+	
<i>Streblospio</i>		+	+
<i>Polydora</i>		+	+
<i>Amphitrite</i>	+		
<i>Harpactacoida</i>		+	+
<i>Ostracoda</i>		+	+
<i>Corophium</i>		+	+
<i>Palaeometes</i>	+		
<i>Cragnon</i>	+		
<i>Carcinides maenas</i>		+	+
<i>Callinectes sapiens</i>		+	
Mosquito larvae	+		

as *Peloscolex*, *Isochaeta*, and *Tubifex*. The remaining individuals were a homogeneous group whose identity could not be determined by external morphology alone. There was a marked morphological variation in setiger number, setae structure, and certain visible internal organs, but positive identification is only possible through sectioning techniques. It is surprising that there is no report of oligochaetes from the United States east coast saltmarsh pools (Table IV, VI), considering the existence of at least several brackish water species (Brinkhurst & Jamieson 1971). The significance of distribution and abundance patterns in Minas Basin deserves further study.

Peloscolex benedeni is a brackish water and marine species of the Atlantic coast (Brinkhurst & Jamieson 1971), but Minas Basin specimens were unusually long, 35 to 55 mm.

Isochaeta hamata (Moore 1905) is a brackish water worm reported only from Massachusetts (Brinkhurst & Jamieson 1971).

Tubifex pseydogaster (Dahl 1960), another brackish water species (Brinkhurst & Jamieson 1971), was distinctive in being relatively short, 12 to 13 mm, and in moving about with whip-like movements, reminiscent of nematodes.

Phylum Arthropoda

Class Arachnida

Order Acarina

Mites were ubiquitous within the pools and appeared in unexpected numbers in A-1, February 1976. No attempt was made to assign specific rank to this difficult taxon which includes 41 recorded species from eastern North America (Newell 1947).

Class Crustacea

Subclass Ostracoda

Ostracods were not separated below the class level, and were collected from all but 2 pools, D-2 and D-3.

Subclass Copepoda

Among copepods, cyclopoids far outnumbered harpacticoids, with calanoids comprising the minority. These arthropods are present in all pools, and are numerically second only to the nematodes. No attempt was made to classify them below subclass level.

Jaera marina (Fabricius 1780) is a common intertidal species, occasionally found in brackish water (Schultz 1975). It was collected from only 1 pool, A-1, and no additional species of isopod were recorded from any of the other pools.

Order Amphipoda

Corophium volutator (Pallas 1766) is an estuarine and intertidal amphipod, common in Europe (Hart 1930; Crawford 1937) but is confined to the Gulf of Maine and Bay of Fundy in the northwest Atlantic (Bousfield 1973). Specimens were collected from A-1, B-1, C-1, E-6, and E-10, and 554 were present in the sample from E-6, 31 May 1976. Of the 36 adults, the female to male ratio in this sample was 11:1, very high, even so early in the year (Hart 1930). The remaining 518 individuals were juveniles.

Gammarus mucronatus Say 1818 was collected from the pools year round but was not a dominant species, as reported elsewhere (Bousfield 1973). Specimens were collected from A-1, B-1, B-9, C-1, D-1, D-2, and E-10. Only in D-1 were they common.

Orchestia grillus Bosc 1802 normally inhabits the marsh surface, nesting among marsh grass roots (Bousfield 1973), but during this survey was found in winter in D-1 and D-2. During winter thaws, they swim about in the rivulets that issue from the ice margins of the pools.

Order Decapoda

Carcinus maenus (Linnaeus 1758) is one of the commonest marine and brackish water brachyurans on the North American east coast (Smith 1964). It was not recorded in Minas Basin before 1953 (Bousfield & Leim 1960), but since that time appears to have become widespread in the area. The record of a specimen from D-1 is in deference to its presence, having been observed in pools and drainage ditches in all 5 marshes.

Class Insecta

Water boatmen have been reported from brackish water (Chu 1949), and they were often abundant in Minas Basin marsh pools i spite of the high salinities (Bailey 1967; Frank 1974). Because of their rapid swimming, they were seldom caught in the benthic sampler.

Family Chironomidae

Larval concentrations of this family were higher in winter than in summer.

Family Hydrophilidae

Only 1 individual of this aquatic beetle family (Chu 1949) was collected from D-3.

Discussion

Faunal Composition

The results indicate that Minas Basin saltmarsh pools contain a benthos which not only exhibits low diversity and high density, but also local and regional variation.

The prime objective of this study was to determine what taxonomic groups comprise the benthos of the saltmarsh pools in Minas Basin. As a result of rigorous searching, and assuming the benthos to have a degree of homogeneity, it is probable that a high percentage of the groups present were isolated. Excepting the occasional giant ciliate and obscure platyhelminthes, no additional taxa were noted during the last few months of study. The distribution of taxa relative to each of the 10 marsh pools is summarized in Table III.

The variation in species composition of these pool communities is evident, because only 3 pools, A-1, D-1, and E-6, ever exceeded 50% of the total taxa. On a local distributional basis, there are only 20 taxa that occurred in at least one-half of the marsh pools, and of these only 12 were found in each of the 5 estuarine marshes (Table VII). Therefore, the apparent uniformity of habitat of these marsh pools is deceptive, for the fauna is diverse and the community composition can vary greatly from pool to pool and from marsh to marsh.

It is difficult to demonstrate seasonal differences in faunal community composition with much confidence because of irregular sampling. Nevertheless, pools A-1, B-1, C-1, and D-1 were sampled in different months and those species having 100% frequency in each sample from their respective pools were selected for comparison with the total number of taxa from that pool (Table VIII). C-1 had the highest percentage (40%) of taxa occurring in every sample, and A-1 was second with 35%. Although sampled 4 times, pool D-1 had only 15% of the 32 taxa repeatedly occur-

Table VII. The 20 taxa occurring in at least one-half of the pools sampled in Minas Basin. Their percentage occurrence in the 10 pools is indicated. The asterisk denotes the 12 taxa occurring in each of the 5 estuaries.

Taxa	Percentage
*Foraminiferida	100
*Rotifera	100
*Nematoda	100
* <i>Hydrobia totteni</i>	100
* <i>Ilyanassa obsoleta</i>	100
*Acarina	100
*Copepoda	100
*Oligochaeta	90
<i>Nematostella vectensis</i>	80
*Insect larvae	80
<i>Etone heteropoda</i>	70
*Ostracoda	70
* <i>Gammarus mucronatus</i>	70
<i>Monocelis durhami</i>	60
<i>Littorina saxatilis</i>	60
* <i>Corophium volutator</i>	60
<i>Protohydra leuckarti</i>	50
<i>Protostatella obscura</i>	50
<i>Nereis diversicolor</i>	50
<i>Polydora ligni</i>	50

ing in samples. Only 1 species, *Hydrobia totteni*, was present in every sample from every pool regardless of season.

A further seasonal analysis was attempted by plotting the percent of total taxa (63) in samples collected in different months from the same pool sampled twice or more (Fig 2). These data indicate the variation that can exist, but should not be construed as representative of extremes.

Despite the absence of data from other marsh systems (Chapman 1960), the absolute numbers of organisms per sample (Appendix I) appear high. On 5 occasions over 4,500 animals were extracted from 225 ml of substrate, and at B-9 and E-10 the figures exceeded 7,000 individuals.

Fauna of Foreign Pools

In Britain, there are marshes comparable to those in Minas Basin. The most intensive work on British saltmarsh pools was done by Nicol (1935) and Brough et al. (1960-61), their data indicating similarity in community structure between their study pools and ours. Fifty-four taxa were reported, 9 fewer than in Minas Basin pools. However, 9 of the 54 were copepod species which were not sorted beyond the ordinal level in our study. Disregarding copepod species, 50% of Minas Basin genera and 19% of Basin species were represented in British pools.

There is no evidence in the literature of intensive work having been done on

Table VIII. Distribution of taxa having 100% frequency in at least 1 of the Minas Basin pools sampled in different months, compared with the total taxa recorded from that pool (Table III).

Taxa	Pool	A-1	B-1	C-1	D-1
	Sampling Date	2.76 5.76 4.77	2.76 7.77	5.76 8.77	7.75 1.76 7.76 3.77
<i>Protohydra leuckarti</i>		+			
<i>Nematostella vectensis</i>			+		+
<i>Prostomatella obscura</i>			+		
Nematoda		+	+	+	
<i>Hydrobia toteni</i>		+	+	+	+
<i>Gemma gemma</i>		+			
<i>Nereis diversicolor</i>					+
<i>Fabricia sabella</i>		+			
Oligochaeta		+		+	
Acarina		+		+	
Ostracoda		+		+	
Copepoda		+		+	
<i>Corophium volutator</i>		+			
<i>Gammarus mucronatus</i>				+	
Insecta larvae		+			
% total taxa from each pool		35%	19%	40%	15%

+ = 100% distribution

Table IX. Checklist of 54 invertebrate benthic taxa recorded from British saltmarsh pools. The right hand column includes those occurring in Minas Basin pools.

Taxa Recorded in British Pools	Hickson 1929	Lebour 1931	Nicol 1933	Nicol 1935	Brough et al. 1960–61	Minas Basin
Phylum Protista						
<i>Elphidium crispum</i>					+	+
Phylum Cnidaria						
<i>Protohydra leuckarti</i>	+			+		++
<i>Syncoryne sarsi</i>				+		
Phylum Nemertea						
<i>Lineus gasserensis</i>			+	+		+
Phylum Rotifera						
Unidentified sp					+	+

Taxa Recorded in British Pools	Hickson 1929	Lebour 1931	Nicol 1933	Nicol 1935	Brough et al. 1960—61	Minas Basin
Phylum Nemetoda						
Unidentified sp					+	+
Phylum Bryozoa						
<i>Bowerbankia gracillema</i>	+				+	+
Phylum Mollusca						
<i>Littorina littorea</i>			+	+		++
<i>Littorina saxatilis</i>			+	+		++
<i>Hydrobia ulva</i>			+	+	+	+
<i>Hydrobia stagnalis</i>	+					+
<i>Mya arenaria</i>				+		++
<i>Mytilus edulis</i>				+		++
<i>Limpontia capitata</i>				+		
<i>Limpontia depressa</i>			+		+	
<i>Alderia modesta</i>				+		++
<i>Macoma balthica</i>			+	+		
Nudibranch (unident.)	+					
<i>Embletonia pallida</i>				+		+
Phylum Annelida						
<i>Manayunkia aestuarina</i>				+		++
<i>Nereis diversicolor</i>			+	+	+	++
<i>Arenicola marina</i>			+	+		
<i>Pygospio elegans</i>				+		++
<i>Polydora</i> larvae					+	+
<i>Eulalia viridis</i>				+		
<i>Dinophilus taeniatus</i>				+		+
<i>Paranais litoralis</i>	+					
Oligochaeta					+	+
Phylum Arthropoda						
Acarina					+	+
Copepoda	+	+				+
<i>Acartia longiremis</i>					+	
<i>Amphiascus giesbrechti</i>					+	
<i>Canuella perplexa</i>					+	
<i>Ectinosoma curticorne</i>					+	
<i>Eurytemora affinis</i>					+	
<i>Laophonte nana</i>					+	
<i>Mesochra lilljeborgi</i>					+	
<i>Nitocra spinipes</i>					+	
<i>Tachidius disipes</i>					+	
<i>Sphaeroma rugicauda</i>	+		+	+	+	
<i>Palaemonetes varians</i>	+		+		+	
<i>Carcinus maenas</i>	+		+	+	+	++
<i>Jaera marina</i>				+		++
<i>Melita palmata</i>				+		
<i>Corophium volutator</i>			+	+	+	++
<i>Crangon vulgaris</i>			+	+		
<i>Gammarus duebeni</i>				+	+	+
<i>Eurydice pulchra</i>					+	
<i>Gnathia oxyuraea</i>					+	
<i>Chironomus aprilius</i>					+	
<i>Limnophilus affinis</i>					+	
<i>Corixa</i>					+	+
<i>Notonecta</i>					+	+
<i>Anurida maritima</i>					+	
Insecta larvae			+	+		+
Total	9	1	14	26	31	29

In the right hand column, + = occurrence at the generic or higher level;
 ++ = occurrence at the specific level.

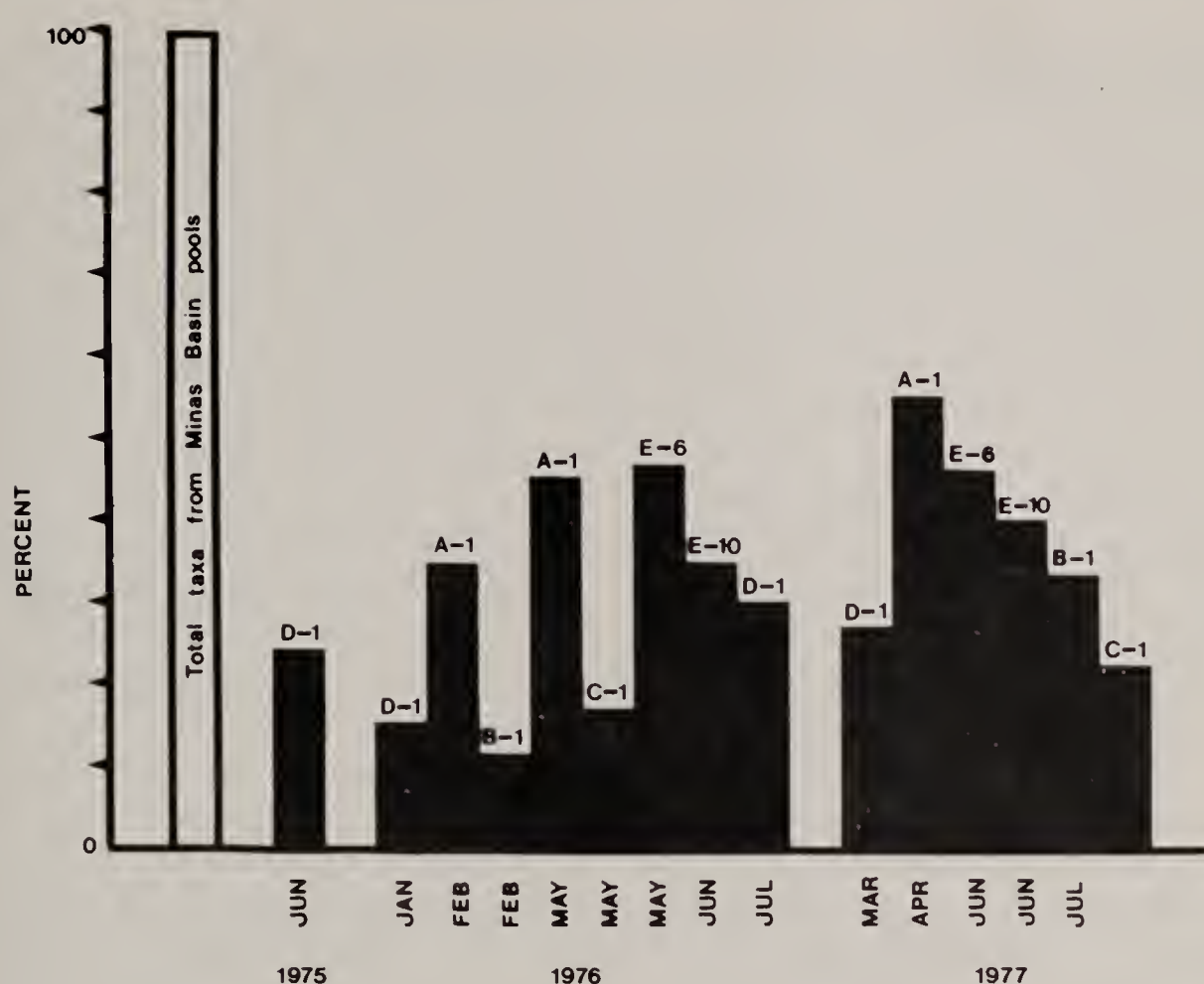


Fig 2 Percent of total taxa comparisons of benthic samples collected in different months and different years from pools sampled twice during 1975-1977.

Table X. Miscellaneous temperature, ice, and salinity measurements at salt marsh pools, Kings County, Minas Basin, 1966-1977. Norenburg's work included small shallow pools not considered by the other authors.

Data Source	Data dates	Temperature range °C	Thickness of ice (cm)	Salinity (‰)	
				Bottom	Surface
Bailey 1967	Jan. to Nov. 1966 June to Nov. 1966	-1.5 to 28.5	50	28.5 - 38.9	20.5 - 39.3
Bleakney (unpubl.)	25 Jan., 1970 27 Jan., 1971		30 46 - 50		
Frank 1974	9 Jan. to 15 Nov. 1973	-1.0 to 26.0	19	22.6 - 39.3	11.9 (10 days rain)
Norenburg 1976	Sept. 1974 to Feb., 1976	-1.5 to 28.0	30	19.7 - 31.9	11.1 - 23.0
Bleakney (unpubl.)	8 March, 1977		68.5		

United States east coast saltmarsh pools which differ in origin and structure from those in Minas Basin (Teal & Teal 1969; Cooper 1974) and therefore could be expected to differ in community structure as well. Teal and Teal (1969) record the fauna collected from pools on Georgia salt marshes, and Nixon and Oviatt (1973) listed those from Bissel Cove embayment, a small body of water in Maine whose description approximates that of E-6 in Minas Basin. The majority of fauna reported in these 3 studies were assigned ranks above the species level, thus permitting only perfunctory comparison with fauna from Minas Basin (Table IX). Only 18 taxa were reported from United States saltmarsh pools. Surprisingly, of the Minas Basin species of molluscs, annelids, and arthropods only 8%, 17%, and 27% respectively were represented in United States pools.

Despite intensive studies of salt marshes of the world (Chapman 1960), there is a paucity of literature and no quantitative studies on saltmarsh pools. Therefore, having only informal written and verbal reports of other geographic regions as bases for comparison, our tentative conclusion is that permanent marsh pools are a unique and rich community component of Minas Basin marshes.

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Appendix I

Numbers of animals per 225 ml.

Pool A-1	23 Feb 1976	13 May 1976	29 Apr 1977	Total
Phylum Cnidaria				
<i>Protohydra leuckarti</i>	2	5	5	12
<i>Nematostella vectensis</i>	11			11
Phylum Platyhelminthes				
<i>Neochildia fusca</i>			7	7
<i>Otomesostoma</i> sp		7		7
<i>Monocelis durhami</i>	20	25		45
Phylum Nemertea				
<i>Prostomatella obscura</i>			2	2
<i>Lineus viridis</i>	6	10	1	17
Phylum Kinorhyncha				
<i>Pycnophyes</i> sp			7	7
Phylum Nematoda				
Unidentified	601	223	1298	2122
Phylum Bryozoa				
<i>Bowerbankia gracilis</i>	4	2		6
Phylum Mollusca				
<i>Littorina littorea</i>	3	1		4
<i>Littorina saxatilis</i>		4		4
<i>Hydrobia totteni</i>	70	31	15	116
<i>Elysia chlorotica</i>		4		4
<i>Mytilus edulis</i>	1			1
<i>Gemma gemma</i>	22	9	6	37
Phylum Annelida				
<i>Eteone heteropoda</i>		1		1
<i>Eteone longa</i>	7			7
<i>Streblospio benedicti</i>			29	29
<i>Pygospio elegans</i>		1	3	4
<i>Polydora ligni</i>		1		1
<i>Fabricia sabella</i>	3	10	78	91
<i>Manayunkia aestuarina</i>			6	6
Oligochaeta	254	146	258	658
Phylum Arthropoda				
Acarina	300	16	5	321
Ostracoda	79	206	61	346
Copepoda	737	752	528	2017
<i>Jaera marina</i>		4		4
<i>Corophium volutator</i>	40	27	22	89
<i>Gammarus mucronatus</i>	1	22		23
<i>Carcinus maenus</i>				
Chironomidae larvae	160	35	153	348
Grand total	2321	1544	2484	6347
Total taxa	19	24	18	31

Pool B-1.	3 Feb 1976	29 July 1977	Total
Phylum Cnidaria			
<i>Nematostella vectensis</i>	33	38	71
Phylum Platyhelminthes			
<i>Otomesostoma</i> sp		4	4
M-6.11.76		1	1
<i>Monocelis durhami</i>		5	5
Phylum Nemertea			
<i>Prostomatella obscura</i>	2	3	5
<i>Lineus viridis</i>		1	1
Phylum Nematoda			
Unidentified	135	1028	2063
Phylum Mollusca			
<i>Littorina littorea</i>		2	2
<i>Littorina saxatilis</i>		1	1
<i>Hydrobia totteni</i>	6	50	56
<i>Stiliger fuscatus</i>		2	2
Phylum Annelida			
<i>Eteone heteropoda</i>		4	4
<i>Nereis diversicolor</i>		8	8
<i>Fabricia sabella</i>		7	7
Oligochaeta		67	67
Phylum Arthropoda			
Acarina		11	11
Ostracoda		37	37
Copepoda		117	117
<i>Corophium volutator</i>		37	37
<i>Gammarus mucronatus</i>		2	2
Chironomidae larvae	4		4
Grand total	180	2325	2505
Total taxa	5	20	21

Pool B-9	6 Nov 1976
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Phylum Cnidaria	
<i>Protohydra leuckarti</i>	2
<i>Nematostella vectensis</i>	80
Phylum Platyhelminthes	
<i>Otomesostoma</i> sp.	58
M-6.11.76	1
<i>Monocelis durhami</i>	7
Phylum Nematoda	
Unidentified	5406
Phylum Bryozoa	
<i>Bowerbankia gracilis</i>	8
Phylum Mollusca	
<i>Hydrobia totteni</i>	469
Phylum Annelida	
<i>Eteone heteropoda</i>	2
<i>Polydora ligni</i>	7
<i>Fabricia sabella</i>	3
<i>Manayunkia aestuarina</i>	5
Oligochaeta	52
Phylum Arthropoda	
Acarina	10
Copepoda	862
<i>Gammarus mucronatus</i>	3
Chironomidae larvae	75
Grand Total	7056
Total taxa	17

Pool C-1	3 May 1976	29 Aug 1977	Total
Phylum Platyhelminthes			
<i>Otomesostoma</i> sp.		9	9
<i>Monocelis durhami</i>	2	3	5
Phylum Nemertea			
<i>Prostomatella obscura</i>	1		1
Phylum Nematoda			
Unidentified	855	868	1723
Phylum Mollusca			
<i>Hydrobia totteni</i>	86	25	111
Phylum Annelida			
<i>Dinophilus</i> sp.	5		5
<i>Nereis diversicolor</i>		1	1
Oligochaeta	15	50	65
Phylum Arthropoda			
Acarina	2	10	12
Ostracoda	18	6	24
Copepoda	111	87	198
<i>Corophium volutator</i>		13	13
<i>Gammarus mucronatus</i>		16	16
Chironomidae larvae	1		1
Grand total	1096	1088	2184
Total taxa	10	11	14

Pool D-1	9 Jul 1975	28 Jan 1976	31 Jul 1976	28 Mar 1977	Total
Phylum Cnidaria					
<i>Protohydra leuckarti</i>	1		2		3
<i>Nematostella vectensis</i>	1816	176	520	62	2574
Phylum Platyhelminthes					
D-6.11.76	3				3
Ty-28.3.77				1	1
E-28.3.77				1	1
S-28.3.77				1	1
Phylum Nemertea					
<i>Prostomatella obscura</i>		18			18
Phylum Nematoda					
Unidentified	876		610	5480	6966
Phylum Bryozoa					
<i>Bowerbankia gracilis</i>				3	3
Phylum Mollusca					
<i>Hydrobia totteni</i>	2193	10	65	94	2362
<i>Alderia modesta</i>		40			40
<i>Elysia chlorotica</i>		2			2
Phylum Annelida					
<i>Dinophilus</i> sp.			1	1	2
<i>Eteone heteropoda</i>	1		1	2	4
<i>Nereis diversicolor</i>	15	1	4	1	21
<i>Heteromastis filiformis</i>			67		67
<i>Streblospio benedicti</i>			10		10
<i>Polydora ligni</i>			8		8
<i>Scoloplos fragilis</i>			2		2
Oligochaeta	743		359	498	1600
Phylum Arthropoda					
Acarina	5			2	7
Ostracoda				36	36
Copepoda	14		49	465	528
<i>Corophium volutator</i>	53		42		95
<i>Gammarus mucronatus</i>	80	4	4	2	90
<i>Orchestia grillus</i>		22			22
<i>Carcinus maenus</i>	1				1
Chironomidae larvae	4			3	7
Grand total	5802	273	1747	6652	14474
Total taxa	14	8	15	16	28

	28 Jan 1976
Pool D-2	
Phylum Cnidaria	
<i>Nematostella vectensis</i>	65
Phylum Nemertea	
<i>Prostomatella obscura</i>	5
Phylum Nematoda	
Unidentified	768
Phylum Mollusca	
<i>Hydrobia totteni</i>	114
Phylum Annelida	
<i>Eteone heteropoda</i>	2
<i>Polydora ligni</i>	1
Phylum Arthropoda	
Acarina	1
<i>Gammarus mucronatus</i>	3
<i>Orchestia grillus</i>	2
Chironomidae larvae	4
Grand total	965
Total taxa	10

	21 Sept 1975
Pool D-3*	
Phylum Cnidaria	
<i>Nematostella vectensis</i>	4
Phylum Mollusca	
<i>Littorina littorea</i>	1
<i>Littorina saxatilis</i>	46
<i>Hydrobia totteni</i>	122
<i>Physa</i> sp	1
Phylum Annelida	
<i>Dinophilus</i> sp	1
<i>Peloscolex benedeni</i>	3
<i>Tubifex pseudogaster</i>	1
Phylum Arthropoda	
Copepoda	23
Corixidae	2
Hydrophilidae	1
Grand total	205
Total taxa	11

*Animals collected from sieveful of floating *Vaucheria* sp

Pool E-1	15 Feb. 1976	31 Aug 1976
Phylum Cnidaria		
<i>Nematostella vectensis</i>		+
Phylum Platyhelminthes		
<i>Otomesostoma</i> sp	6	
Phylum Nematoda		
Unidentified	1903	+
Phylum Mollusca		
<i>Littorina saxatilis</i>	112	+
<i>Hydrobia totteni</i>	1604	+
Phylum Annelida		
<i>Pygospio elegans</i>		+
Oligochaeta	2	
Phylum Arthropoda		
Acarina	9	
Ostracoda	53	
Copepoda	53	+
Chironomidae larvae	6	
Grand total	3748	
Total taxa	9	6

Pool E-6	31 May 1976	1 Jun 1977	Total
Phylum Cnidaria			
<i>Protohydra leuckarti</i>	59	19	78
Phylum Platyhelminthes			
T-1003.11	2	8	10
<i>Otomesostoma</i> sp		11	11
<i>Monocelis durhami</i>	1		1
Phylum Kinorhyncha			
<i>Pycnophyes</i> sp	24	12	36
Phylum Nematoda			
Unidentified	1206	2399	3605
Phylum Bryozoa			
<i>Bowerbankia gracilis</i>	1		1
Phylum Mollusca			
<i>Littorina littorea</i>		1	1
<i>Littorina saxatilis</i>	1		1
<i>Hydrobia totteni</i>	15	8	23
<i>Ilyanassa obsoleta</i>	3	5	8
<i>Mytilus edulis</i>		1	1
<i>Geukensia demissa</i>	1	1	2
<i>Gemma gemma</i>	1		1
<i>Mya arenaria</i>		1	1
Phylum Annelida			
<i>Eteone heteropoda</i>	2	1	3
<i>Eteone longa</i>	3	1	4
<i>Nereis diversicolor</i>	4	6	10
<i>Heteromastis filiformis</i>	6	18	24
<i>Streblospio benedicti</i>	4	2	6
<i>Pygospio elegans</i>	4		4
<i>Scoloplos fragilis</i>	28	3	31
<i>Manayunkia aestuarina</i>	1	2	3
Oligochaeta	51	40	91
Phylum Arthropoda			
Acarina	27	8	35
Ostracoda	220	121	341
Copepoda	894	909	1803
<i>Corophium volutator</i>	554	146	700
Chironomidae larvae	3	4	7
Grand total	3115	3600	6715
Total taxa	25	24	29

Pool E-10	19 Jun 1976	24 Jun 1977	Total
Phylum Cnidaria			
<i>Protohydra leuckarti</i>	19	15	34
<i>Nematostella vectensis</i>	2	3	5
Phylum Platyhelminthes			
T-1003.11	18	9	27
<i>Otomesostoma</i> sp	2	78	80
<i>Monocelis durhami</i>		1	1
Phylum Nematoda			
Unidentified	3643	5780	9423
Phylum Mollusca			
<i>Littorina saxatilis</i>	2	5	7
<i>Hydrobia totteni</i>	444	460	904
<i>Hiatella striata</i>		1	1
Phylum Annelida			
<i>Eteone heteropoda</i>	2	1	3
<i>Eteone longa</i>	1	3	4
<i>Eteone</i> sp. juvenile	18		18
<i>Nereis diversicolor</i>	18	27	45
<i>Nereis</i> sp. juvenile	1		1
<i>Heteromastis filiformis</i>		2	2
<i>Streblospio benedicti</i>		6	6
<i>Pygospio elegans</i>	1	1	2
<i>Polydora ligni</i>	187	31	218
<i>Manayunkia aestuarina</i>	7	34	41
Oligochaeta	109	357	466
Phylum Arthropoda			
Acarina	10	10	20
Ostracoda	12	31	43
Copepoda	309	354	663
<i>Corophium volutator</i> (Juvenile)	19		19
<i>Gammarus mucronatus</i>		3	3
Grand total	4829	7212	12036
Total taxa	20	22	23

DISTRIBUTION OF PELECYPODS AND GASTROPODS IN THE BAY OF FUNDY AND EASTERN GULF OF MAINE

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One hundred and thirteen molluscan species (63 pelecypods, 49 gastropods, and one scaphopod) have been identified from the Bay of Fundy and eastern Gulf of Maine at depths between 27 and 256 m. Ten faunal groupings of mappable areal extent (biotopes) are recognizable. The biotopes are related to substrate type (units described by Fader et al. 1977) and to depth. The total areal distribution, depth, and substrate preferences of the index species are noted. The biotopes of greatest areal extent have as their index species *Astarte undata* Gould, *Cerastoderma pinnulatum* (Conrad), *Astarte subaequilatera* Sowerby, and *Cyclocardia borealis* (Conrad) respectively. The index species *Nuculana pernula* (Müller), *Yoldia myalis* (Courthouy), and *Yoldiella inconspicua* Verrill and Bush are deposit feeders indicative of fine-grained substrates and generally quiet waters. The other index species are suspension feeders, a type normally associated with coarse sediments and stronger currents.

Introduction

In recent years, scientists from the Atlantic Geoscience Centre have conducted cruises to the Bay of Fundy and eastern Gulf of Maine. G.B. Fader and L.H. King, in 1971 and 1973, were interested in the physical setting of the area and used echogram profiles supplemented by bottom samples to identify and trace the extent of the various sedimentary units (Fader et al. 1977). Their Van Veen grab sample stations were located on the basis of echogram characteristics and/or where morphology of the sea floor suggested a change in sediment type. The sampling program of G. Vilks and F.J.E. Wagner in 1975 was confined to the immediate approaches of the Bay of Fundy and to the bay itself. One of the objectives of this cruise was a study of the distribution of foraminiferal and molluscan faunas in the area.

The purpose of this paper is to synthesize the molluscan species distribution data derived from the 1971, 1973, and 1975 cruises to the Bay of Fundy and the eastern part of the Gulf of Maine and to investigate the relationship of the faunal associations to water depth and substrate type in the 27 m to 256 m depth range. Ninety-eight species (52 pelecypods, 45 gastropods, and one scaphopod) were recognized previously and presence/absence data for these forms were analyzed using Q-mode cluster analysis (Wagner 1977). The data used in this analysis resulted in the definition of nine biotopes at the 0.2 level of similarity.

Marine Geology

Sedimentary units on the Scotian Shelf were informally named by King (1970). Subsequently, 5 of these units were traced into the Gulf of Maine and the Bay of Fundy (Fader et al. 1977) (Fig 1). Scotian Shelf drift was the name applied to material deposited by the Pleistocene glaciers. It consists of a poorly sorted mixture of clay-to sand-sized particles with angular pebbles, cobbles, and boulders. This unit, presenting a rough and undulating surface, forms a narrow zone bearing in a general southerly direction across the western part of the Bay of Fundy and the eastern part of the Gulf of Maine. The sediment surface has been modified by modern currents in the inner Bay of Fundy and at the entrance to the bay. In part contemporaneous



Fig 1. Sedimentary units in the Bay of Fundy and eastern Gulf of Maine (after Fader et al 1977).

with the drift is a deposit of proglacial clayey and sandy silt, the Emerald silt. This unit, which in places occupies pockets in the drift and elsewhere interfingers with it, is confined to the outer Gulf of Maine. The Sambro sand in part overlies the Scotian Shelf drift and is in part a lateral equivalent of the Emerald silt. It is found at depths below about 120 m on the Scotian Shelf but extends into shallower depths in the Gulf of Maine and the Bay of Fundy. The sand is fine- to coarse-grained and forms a firm surface. Locally there may be more than 10% gravel. It is of widespread occurrence in the eastern Gulf of Maine and in the eastern Bay of Fundy. The LaHave clay overlies the Scotian Shelf drift and Emerald silt and is generally contemporaneous with the Sable Island sand and gravel. The clay is common in the western part of the map-area where it is present in isolated depressions over the surface of the drift. In the Bay of Fundy, the sizeable area of LaHave clay east and northeast of Grand Manan Island coincides generally with an area of relatively low current velocities. The Sable Island sand and gravel unit varies from predominantly medium- to coarse-grained, well sorted sand to predominantly coarse gravel with well rounded boulders. It occurs along the eastern margin of the Gulf of Maine at depths less than 90 m.

Methods

As stated previously, 9 associations (biotopes) had been determined using cluster analysis based on presence/absence data (Wagner 1977). However, this method did not take into account the abundance of some species and the scarcity of others. The study also did not consider whether or not the individuals were actually living at the site of collection or if their presence there was the result of passive transport. In this regard the state of preservation of individual pelecypods and gastropods can be very informative. If the soft parts are present the individual was probably living at the site of collection. Lacking the soft parts, the shell itself can be used to determine whether or not the specimen was in situ. Intact pelecypod shells and fresh appearing gastropod shells (i.e. shells showing their original shiny surface or, for those species with a periostracum having the periostracum still adhering to the shell) have probably not been moved from the place where these organisms were living. The same may be said for disarticulated, but otherwise well preserved, pelecypod valves. Badly eroded shells and fragments suggest working of the deposit and possible transport of the shell material. Severe erosion of a shell is manifested in various ways. An ornamented shell may be largely or completely smoothed while a thick shell could be much reduced in thickness and a thin one partly destroyed.

The indicator assemblages established in the present study are based on the following criteria for each species: 1) the relative abundance of the species at each locality at which it is present, 2) whether or not the species was in situ or had been transported, and 3) the number of stations at which the species was found. To estimate the total number of specimens in a sample, and to determine the relative abundance of each species, a weighted value was given to each specimen as follows. A complete, in situ specimen was given a value of 1.0, a single pelecypod valve or a slightly to moderately worn gastropod received a value of 0.5, and a fragment was given a value of 0.1. These weighted values were then converted to percentages.

The change in census method, in conjunction with the extended areal coverage and greater number of species involved, has resulted in a change in the number of associations to 10 from the previously designated 9. Some of the assemblages correspond to those reported previously (Wagner 1977), whereas others differ significantly. In the present study only 1 species is designated as an index species for an assemblage; in the former study an index assemblage was used to define the respective biotopes. Criteria for the selection of an index species in this study are that it be present at 80%, or more, of the stations of the biotope for which it is index species and that, usually, it is the most abundant in situ species at each locality at which it occurs within the biotope. The term 'biotope' is used because the areas are based on assemblages that are, primarily, in situ rather than being based on a collection of specimens assembled after death (i.e. a taphotope). In those instances in which the most abundant species at a station is not the index form, the index species is generally present and along with other species comprise an association that can be related to a particular biotope. In the few cases where no index species was present, the stations were assigned to a biotope on a 'best fit' basis, using geographic proximity and subordinate species association criteria. Geographic distribution of the biotopes is shown in Figure 2. Table I is a complete list of species and the biotope(s) in which each species occurs.

Results and Discussion

A total of 220 additional stations have been added to the original 38 occupied in 1975. At 68 of these the grab sampler came up empty. A further 26 samples were



Fig 2.
Areal distribution of biotopes in the Bay of Fundy and eastern Gulf of Maine (Barren areas and areas yielding only unidentifiable fragments are unshaded).

lacking molluscs or yielded only unidentifiable fragments (Fig 2). The additional coverage has increased the number of species identified by 11 pelecypods and 4 gastropods for a total of 113 species (Appendix). Only shelled gastropods were encountered in the samples.

BIOTOPES

The 10 biotopes are defined in the following terms. An index species is designated based on the criteria outlined previously and used to establish the geographic distribution and number of biotopes. Then the common species, i.e. those having a frequency of 20%, or more of the stations in the biotope, are determined as are species apparently restricted to the biotope. The typical depth range and preferred substrate for each biotope are determined on the basis of the occurrence of in situ specimens of the index species. Table I lists all species identified and indicates in which biotope(s) each species occurs. Common species and restricted species for each biotope may be determined from this table. Index species, depth range, and typical substrate for each biotope are listed in Table II.

BIOTOPE 1. Biotope 1 is ubiquitous in terms of water depth and ranges between 33 and 243 m. Two main occurrences are along the north shore of the Bay of Fundy and across the central part of the eastern Gulf of Maine. Depth range in the former area is between 33 and 93 m and in the latter area between 78 and 212 m. Other ex-

Table I Percentage occurrence of species in terms of the number of stations at which the species occurs in a particular biotope/the total number of stations in that biotope. Index species occurrences are in italics.

BIOTOPE	1	2	3	4	5	6	7	8	9	10
NUMBER OF STATIONS	53	8	19	26	17	7	8	9	11	5
<i>Astarte subaequilatera</i> Sowerby	6	25	16	88	35	43	13	22	45	40
<i>Astarte undata</i> Gould	91	63	42	23	24	-	13	22	18	20
<i>Bathyarca pectunculinoidea</i> (Scacchi)	15	-	-	27	12	14	-	22	91	40
<i>Yoldiella inconspicua</i> Verrill and Bush	2	-	-	4	-	-	-	11	9	80
<i>Placopecten magellanicus</i> (Gmelin)	25	13	63	19	29	29	13	11	9	-
<i>Anomia squamula</i> Linné	23	63	21	23	18	14	13	-	9	-
<i>Anomia simplex</i> d'Orbigny	19	-	21	19	18	-	13	11	45	-
<i>Nuculana pernula</i> (Müller)	19	38	5	15	6	-	13	88	9	-
<i>Hiatella arctica</i> (Linné)	8	75	32	4	12	14	-	-	9	-
<i>Periploma fragile</i> (Totten)	4	-	-	-	-	14	13	22	9	-
<i>Chlamys islandica</i> (Müller)	15	38	21	19	18	-	-	-	9	-
<i>Puncturella noachina</i> (Linné)	98	38	16	12	12	-	-	-	9	-
<i>Nucula tenuis</i> (Montagu)	8	-	5	12	-	-	-	22	9	-
<i>Epitonium greenlandicum</i> (Perry)	4	13	11	8	-	-	-	11	18	-
<i>Astarte striata</i> (Leach)	2	-	-	-	-	-	13	-	18	-
<i>Oenopota declivis</i> (Lovén)	8	-	-	12	18	-	-	-	9	-
<i>Turbonilla interrupta</i> (Totten)	2	-	-	8	6	-	-	-	9	-
<i>Palliolum imbrifer</i> (Lovén)	4	-	5	4	-	-	-	-	9	-
<i>Neptunea decemcostata</i> (Say)	6	-	11	-	-	-	-	-	9	-
<i>Cerastoderma pinnulatum</i> (Conrad)	26	63	95	15	18	43	13	11	-	-
<i>Cyclocardia borealis</i> (Conrad)	25	50	53	27	88	43	13	11	-	-
<i>Natica clausa</i> Broderip and Sowerby	8	-	-	4	6	14	-	11	-	-
<i>Thyasira gouldii</i> (Philippi)	2	38	5	-	-	-	13	11	-	-
<i>Axinopsida orbiculata</i> (Sars)	2	-	-	-	-	14	-	11	-	-
<i>Colus pubescens</i> (Verrill)	2	-	-	4	-	-	13	22	-	-
<i>Palliolum striatum</i> (Müller)	8	13	21	-	-	-	-	11	-	-
<i>Yoldia myalis</i> (Couthouy)	6	38	32	4	6	86	13	-	-	-
<i>Crenella glandula</i> Totten	4	38	11	8	6	14	13	-	-	-

BIOTOPE		1	2	3	4	5	6	7	8	9	10
NUMBER OF STATIONS		53	8	19	26	17	7	8	9	11	5
<i>Propebela turricula</i> (Montagu)		4	25	5	4	-	14	25	-	-	-
<i>Pandora gouldiana</i> Dall		2	-	5	-	-	14	25	-	-	-
<i>Cylichna alba</i> Brown		2	-	-	4	6	-	13	-	-	-
<i>Arctica islandica</i> (Linné)		9	-	15	-	-	43	100	-	-	-
<i>Nassarius trivittatus</i> (Say)		2	-	-	-	-	14	13	-	-	-
<i>Lunatia pallida</i> (Broderip and Sowerby)		6	13	11	-	-	14	13	-	-	-
<i>Ensis directus</i> (Conrad)		2	-	-	-	-	-	13	-	-	-
<i>Modiolus modiolus</i> (Linné)		8	100	16	8	18	29	-	-	-	-
<i>Tellina agilis</i> Stimpson		4	-	-	-	6	14	-	-	-	-
<i>Clinocardium ciliatum</i> (Fabricius)		6	-	-	-	-	14	-	-	-	-
<i>Velutina velutina</i> (Müller)		6	38	11	-	6	-	-	-	-	-
<i>Crenella decussata</i> (Montagu)		2	-	5	8	6	-	-	-	-	-
<i>Mya arenaria</i> Linné		2	-	5	-	6	-	-	-	-	-
<i>Astarte castanea</i> (Say)		2	-	-	-	6	-	-	-	-	-
<i>Tachyrhynchus erosus</i> (Couthouy)		2	-	11	12	-	-	-	-	-	-
<i>Crucibulum striatum</i> (Say)		2	-	11	4	-	-	-	-	-	-
<i>Nuculana minuta</i> (Fabricius)		2	-	-	4	-	-	-	-	-	-
<i>Retusa obtusa</i> (Montagu)		2	-	-	8	-	-	-	-	-	-
<i>Crassostrea virginica</i> (Gmelin)		2	25	5	-	-	-	-	-	-	-
<i>Margarites costalis</i> (Gould)		2	-	16	-	-	-	-	-	-	-
<i>Mercenaria mercenaria</i> (Linné)		2	-	5	-	-	-	-	-	-	-
<i>Spisula polynyma</i> (Stimpson)		2	-	5	-	-	-	-	-	-	-
<i>Mya truncata</i> Linné		4	-	5	-	-	-	-	-	-	-
<i>Buccinum</i> sp.		4	-	11	-	-	-	-	-	-	-
<i>Liocyma fluctuosa</i> (Gould)		2	-	5	-	-	-	-	-	-	-
<i>Astarte borealis</i> Schumacher		2	-	-	-	-	-	-	-	-	-
<i>Macoma</i> sp.		2	-	-	-	-	-	-	-	-	-
<i>Mesodesma arctatum</i> (Conrad)		2	-	-	-	-	-	-	-	-	-
<i>Musculus niger</i> (Gray)		2	-	-	-	-	-	-	-	-	-
<i>Thyasira flexuosa</i> (Montagu)		2	-	-	-	-	-	-	-	-	-
<i>Yoldiella frigida</i> (Torell)		2	-	-	-	-	-	-	-	-	-
<i>Buccinum undatum</i> Linné		-	13	-	-	-	-	13	11	-	-
<i>Delectopecten vitreus</i> (Gmelin)		-	13	-	-	-	-	-	11	-	-
<i>Littorina littorea</i> Linné		-	13	-	-	-	14	-	-	-	-

BIOTOPE		1	2	3	4	5	6	7	8	9	10
NUMBER OF STATIONS		53	8	19	26	17	7	8	9	11	5
<i>Trichotropis borealis</i> Broderip and Sowerby		-	13	5	8	12	-	-	-	-	-
<i>Crenella faba</i> (Müller)		-	13	-	-	6	-	-	-	-	-
<i>Turritelopsis acicula</i> (Stimpson)		-	13	-	4	-	-	-	-	-	-
<i>Panomya arctica</i> (Lamarck)		-	13	5	-	-	-	-	-	-	-
<i>Acirsa costulata</i> (Mighels and Adams)		-	25	-	-	-	-	-	-	-	-
<i>Anachis avara</i> (Say)		-	13	-	-	-	-	-	-	-	-
<i>Macoma calcareo</i> (Gmelin)		-	38	-	-	-	-	-	-	-	-
<i>Moelleria costulata</i> (Möller)		-	25	-	-	-	-	-	-	-	-
<i>Yoldia limatula</i> (Say)		-	13	-	-	-	-	-	-	-	-
<i>Thracia septentrionalis</i> Jeffreys		-	-	11	-	6	-	-	-	-	-
<i>Alvania janmayeni</i> (Friele)		-	-	5	-	-	-	-	-	-	-
<i>Cingula aculeus</i> (Gould)		-	-	5	-	-	-	-	-	-	-
<i>Colus pygmaeus</i> (Gould)		-	-	5	-	-	-	-	-	-	-
<i>Dacrydium vitreum</i> (Holböller)		-	-	5	-	-	-	-	-	-	-
<i>Limopsis minuta</i> (Philippi)		-	-	5	-	-	-	-	-	-	-
<i>Lischkeia otto</i> (Philippi)		-	-	5	-	-	-	-	-	-	-
<i>Neptunea despecta</i> (Linné)		-	-	5	-	-	-	-	-	-	-
<i>Oenopota harpularia</i> (Couthouy)		-	-	5	-	-	-	-	-	-	-
<i>Skeneopsis planorbis</i> (Fabricius)		-	-	5	-	-	-	-	-	-	-
<i>Spisula solidissima</i> (Dillwyn)		-	-	5	-	-	-	-	-	-	-
<i>Propebela cancellata</i> (Mighels and Adams)		-	-	-	4	-	-	-	-	9	-
<i>Colus spitzbergensis</i> (Reeve)		-	-	-	4	43	-	-	11	-	-
<i>Alvania carinata</i> Mighels and Adams		-	-	-	4	14	13	-	-	-	-
<i>Yoldia sapotilla</i> (Gould)		-	-	-	4	-	13	-	-	-	-
<i>Admete couthouyi</i> (Jay)		-	-	-	4	-	-	-	-	-	-
<i>Calliostoma occidentale</i> (Mighels and Adams)		-	-	-	4	-	-	-	-	-	-
<i>Cyclopecten pustulosus</i> Verrill)		-	-	-	4	-	-	-	-	-	-
<i>Lepeta caeca</i> (Müller)		-	-	-	4	-	-	-	-	-	-
<i>Limacina lesueurii</i> (d'Orbigny)		-	-	-	4	-	-	-	-	-	-
<i>Margarites groenlandicus</i> (Gmelin)		-	-	-	4	-	-	-	-	-	-

BIOTOPE		1	2	3	4	5	6	7	8	9	10
NUMBER OF STATIONS		53	8	19	26	17	7	8	9	11	5
Megayoldia	thraciaeformis (Storer)	-	-	-	4	-	-	-	-	-	-
Palliolum	subimbrifer (Verrill and Bush)	-	-	-	4	-	-	-	-	-	-
Scaphander	punctostriatus Mighels	-	-	-	4	-	-	-	-	-	-
Solariella	varicosa (Mighels and Adams)	-	-	-	4	-	-	-	-	-	-
Boreotrophon	clathratus (Linné)	-	-	-	-	-	-	-	-	-	-
Buccinum	ciliatum (Fabricius)	-	-	-	-	6	-	-	-	-	-
Musculus	discors (Linné)	-	-	-	-	12	-	-	-	-	-
Colus	stimpsoni (Mörch)	-	-	-	-	-	-	13	-	-	-
Lunatia	triseriata (Say)	-	-	-	-	-	14	-	11	-	20
Aporrhais	occidentalis (Beck)	-	-	-	-	-	14	-	-	-	-
Nucula	proxima Say	-	-	-	-	-	14	-	-	-	-
Nuculana	messanensis (Seguenza) ?	-	-	-	-	-	14	-	-	-	-
Pandora	inornata (Verrill and Bush)	-	-	-	-	-	14	-	-	-	-
Thyasira	equalis (Verrill and Bush)	-	-	-	-	-	14	-	-	-	-
Velutina	undata Brown	-	-	-	-	-	14	-	-	-	-
Nucula	delphinodonta Mighels and Adams	-	-	-	-	-	14	-	-	-	-
Haminoea	solitaria (Say)	-	-	-	-	-	-	13	-	-	20
Hydrobia	totteni Morrison	-	-	-	-	-	-	13	-	-	-
Lucinoma	filosa (Stimpson)	-	-	-	-	-	-	13	-	-	-
Lyonsia	hyalina (Conrad)	-	-	-	-	-	-	13	-	-	-
Solariella	obscura (Couthouy)	-	-	-	-	-	-	13	-	-	-
Yoldiella	fraterna (Verrill and Bush)	-	-	-	-	-	-	13	-	-	60

Table II. Depth and substrate relationships of the molluscan biotopes.

BIOTOPE	INDEX SPECIES	DEPTH* RANGE "A"	DEPTH** RANGE "B"	SUBSTRATE
1	<i>Astarte undata</i>	33-243m	33-243m	Scotian Shelf drift, Sambro sand
2	<i>Modiolus modiolus</i>	64-73m	27-73m	Sambro sand
3	<i>Cerastoderma pinnulatum</i>	34-128m	34-137m	Sambro sand
4	<i>Astarte subaequilatera</i>	79-223m	55-223m	Scotian Shelf drift
5	<i>Cyclocardia borealis</i>	60-174m	60-230m	Sambro sand
6	<i>Yoldia myalis</i>	33-156m	33-165m	Sambro sand
7	<i>Arctica islandica</i>	31-40m	29-40m	Sambro sand, La Have clay
8	<i>Nuculana pernula</i>	62-241m	62-241m	La Have clay
9	<i>Bathyarca pectunculoides</i>	190-232m	134-245m	Scotian Shelf drift
10	<i>Yoldiella inconspicua</i>	148-192m	148-256m	Scotian Shelf drift, La Have clay, Sambro sand

* DEPTH RANGE "A" - Depth range for the biotope based on occurrences of complete specimens of the index species

** DEPTH RANGE "B" - Depth range for the biotope including occurrences of single valves of the index species

pressions of this biotope in the Gulf of Maine are patchy; the greatest depth observed was 243 m. The majority of the 53 stations included in Biotope 1 were divided about equally between the Scotian Shelf drift and the Sambro sand substrates. The index species, *Astarte undata* was identified from 29 stations other than those of Biotope 1, being present in all biotopes except Biotope 6. The depth range observed for in situ specimens of 33 to 243 m indicates a downward extension of range for *A. undata* from the range of 9 to 190 m derived from the literature (references marked with an asterisk). *Astarte*'s prefer a coarse, often gravelly substrate in areas of moderate water movement. They burrow shallowly so that the inhalent and exhalent apertures at the posterior tip of the shell project a few millimetres above the surface of the substrate. The buried animals have been observed to emerge at night and crawl on the sediment surface, but the reason for this behavior is unknown (Stanley 1970). *A. undata* favors the Scotian Shelf drift and the Sambro sand substrate, although a few complete individuals were collected also from the Emerald silt, the LaHave clay, and the Sable Island sand and gravel. The 5 restricted species (Table I) in this biotope were present at only 1 station each.

BIOTOPE 2. This biotope is relatively restricted; it occurs over a depth range of 27 to 73 m and is associated with the Sambro sand. Although this biotope includes only 8 stations, it contains 18 species that are present in 20% of the stations. However, many of these are common in other biotopes as well. Three of the common species are restricted to the biotope. The biotope occurs in the central and upper parts of the Bay of Fundy. A single-station occurrence at a depth of 141 m south of Grand Manan Island was characterized by disarticulated, but unabraded, valves of the index species, *Modiolus modiolus*, plus numerous fragments of *M. modiolus*. Although *M. modiolus* was the most abundant constituent at this station, the assemblage could possibly have been assigned to another biotope.

In addition to being present at the 8 stations of Biotope 2, *M. modiolus* was found at 14 other stations distributed among Biotopes 1, 3, 4, 5 and 6. Literature records suggest a depth range for *M. modiolus* between low water and 280 m. Complete specimens were found in the study area at depths between 27 and 180 m with the majority no deeper than about 90 m. *M. modiolus* is a common cold-water mussel. It attaches on rocky shores, but at greater depths and on soft substrates it forms part of the infaunal benthos. The species is gregarious and is found typically in groups of from 30 to 40 individuals occupying a one-half square meter area (Stanley 1970). All but two occurrences of complete specimens of this suspension-feeder were in the Sambro sand.

BIOTOPE 3. The major occurrences of Biotope 3 are in the eastern part of the Gulf of Maine. A northern occurrence of this biotope has a general depth range between 34 and 106 m with 2 stations at 137 m. At these latter 2 stations only single valves of the index species, *Cerastoderma pinnulatum*, were recovered (this may indicate a borderline situation). A southern expression of this biotope occurs within a depth range of 57 to 128 m. Two single-station occurrences in the central Bay of Fundy were at depths of 62 and 70 m. The substrate for these 2 stations, as well as for the northern group of stations in the Gulf of Maine, is the Sambro sand. The southern group of Gulf of Maine stations are in the Sable Island sand.

Cerastoderma pinnulatum was found at 31 stations other than those of Biotope 3 and in all biotopes except Biotopes 9 and 10. Depth range for the species according to the literature is between 0 and 110 m. In the study area in situ specimens were found as deep as about 140 m and these were usually associated with a sand substrate. This is in keeping with its function as a suspension feeder. Most occurrences were in the Sambro sand with the Sable Island sand second in importance.

BIOTOPE 4. This biotope has a relatively patchy distribution and is best expressed in the western part of the Bay of Fundy with 1 station in the central part of the bay. Several other areas occur in the Gulf of Maine. The shallowest occurrence is at 55 m, but most occurrences of the biotope usually fall within the 110 to 223 m range. This biotope is typically associated with the Scotian Shelf drift, although there are several occurrences on the LaHave clay and Sambro sand and one on the Emerald silt.

The index species, *Astarte subaequilatera*, was present at 88% of the stations of Biotope 4 as well as at 25 stations distributed fairly equally among the other 9 biotopes. Substrate does not appear to be critical for this species. The Scotian Shelf drift was most favorable, but the species was also common in the Sambro sand and the LaHave clay. The species was found at depths between 30 and 230 m in the study area; elsewhere it is known from depths as great as 780 m. This species is similar in life style to *A. undata*.

BIOTOPE 5. Biotope 5 also shows a comparatively heterogeneous distribution. All but 2 localities are in the Gulf of Maine. The strongest expression of this biotope is in an area adjacent to Biotope 4 south of Grand Manan Island. The inclusion of

presumably untransported single-valve occurrences of the index species would give a tentative lower limit of range for this biotope of 230 m compared to 174 m based on in situ specimens of the index species. This biotope is strongly associated with the Sambro sand.

Cyclocardia borealis, the index species, also a suspension feeder, was present at 88% of the stations in Biotope 5 and at 39 stations in other biotopes. It is associated with Biotopes 1, 2, 3, 4, 6, 7, and 8 as well as with 5. The depth range for this species in the study area is between 30 and 180 m although most specimens were collected from depths less than 90 m. This accords well with the low water to 90 m cited in the literature (references marked with an asterisk). The species favors sand substrate and the majority of occurrences in the study area were in the Sambro sand followed by the Sable Island sand and LaHave clay. It is usually found in areas of moderately strong currents (Stanley 1970).

BIOTOPE 6. The chief expression of this biotope is in the south-western Bay of Fundy area. Two single-station occurrences have been identified in the Gulf of Maine at depths of 156 and 165 m. The depth range for the Bay of Fundy stations is between 33 and 156 m, with 4 of these 5 stations less than 85 m. The biotope is usually associated with the Sambro sand.

The index species, *Yoldia myalis*, also occurs in biotopes other than Biotope 6 (see Table I). Complete specimens were collected over a depth range of 30 to 160 m with most coming from depths of less than 90 m. This is in agreement with previous studies (references marked with an asterisk). *Y. myalis* was found almost exclusively in the Sambro sand. The species is a deposit feeder. When buried, proboscoidal feeding takes place completely beneath the sediment surface. It can also move quite actively on the sediment surface (Stanley 1970).

BIOTOPE 7. This is a shallow-water biotope of restricted depth range. It is recognized in the southern approaches to the Bay of Fundy (depth 31 - 33 m) and off the New Brunswick coast north of Grand Manan Island (29-40 m). Four isolated occurrences in the Gulf of Maine were at depths between 82 and 212 m. Three of these were based on fragmentary evidence and the fourth on a single, small, complete specimen that may have been adventitious. In each case, however, the strongest association, based on other criteria, appears to be with Biotope 7. The stations in the entrance to the Bay of Fundy were associated with the Sambro sand and those off the New Brunswick coast with the LaHave clay.

Arctica islandica, index species for the biotope, was identified from only 9 stations in other biotopes. Complete specimens were recorded from Biotopes 1 and 6, and fragments only from Biotope 3. Occurrences of this species were divided equally between the Sambro sand and the LaHave clay. Nicol (1951) gives a depth range of between 10 and 280 m for the species. In the study area, complete specimens were found at depths down to 156 m. In New England waters, *A. islandica* is harvested as a moderately important source of sea food (Jacobson & Emerson 1971).

BIOTOPE 8. This biotope is found, primarily, northeast of Grand Manan Island adjacent to the New Brunswick coast at depths between 62 and 133 m. An isolated occurrence was identified in the entrance to the Bay of Fundy (depth 166 m) and 4 such occurrences were noted in the Gulf of Maine between 102 and 241 m. The biotope is associated primarily with the LaHave clay.

The index species, *Nuculana pernula*, was found at 19% of the stations in Biotope 1, 15% in Biotope 4 and 5%, 6%, 12%, and 9% respectively in Biotopes 3, 5, 7, and 9. In Biotope 8, it was present at 88 of the stations. The majority of in situ occurrences were in the LaHave clay with the Scotian Shelf drift being secondary in importance. Complete specimens were found over a range of 20 to 250 m in the study area, a considerable extension over the literature record of 25 to 60 m. *N. per-*

nula's association with a fine-grained substrate is consistent with its role as a deposit feeder (Stanley 1970).

BIOTOPE 9. The 2 major expressions of this biotope are in the Gulf of Maine southeast and southwest of Grand Manan Island and there are several isolated occurrences elsewhere in the Gulf of Maine. This biotope is indicative of relatively deep waters; the observed depth range is between 134 and 245 m. Most stations comprising the biotope were associated with the Scotian Shelf drift.

The index species, *Bathyarca pectunculoides*, was present at 90% of the stations of Biotope 9. It was also represented in Biotopes 1, 4, 5, 6, 8 and 10. The preferred substrate appears to be the Scotian Shelf drift, a substrate that provides suitable support for this bysally attached species. Four occurrences of in situ specimens were also noted in the LaHave clay. The species was found at depths between 60 and 240 m, well within its recorded range of 9 to 1400 m (references marked with an asterisk).

BIOTOPE 10. Although this biotope is represented by only 5 isolated occurrences, the abundance of *Yoldiella inconspicua* at four of these sites and its rarity in other biotopes, corroborates the validity of distinguishing this faunal association as a biotope. The fifth station is assigned to Biotope 10 because of the presence of *Yoldiella fraterna*. *Y. fraterna*, a species unique to the biotope, was present at 60% of the stations. All occurrences of Biotope 10 are in the Gulf of Maine and its depth ranges between 148 and 256 m. Most stations were associated with the Scotian Shelf drift, with 1 each in the Sambro sand and the LaHave clay.

Yoldiella inconspicua was present also in Biotopes 1, 4, 8, and 9. In the study area complete specimens were collected from depths between 140 and 230 m which is in agreement with previous observations. *Y. inconspicua* is a minute form having a maximum length of 3 mm. As a member of the Superfamily Nuculacea it is probably a deposit feeder.

Summary and Conclusions

The Bay of Fundy—eastern Gulf of Maine area supports an extensive and varied molluscan fauna composed of at least 63 species of pelecypods and 49 species of gastropods. Ten biotopes have been defined and an index species has been designated for each. The salient features of each biotope are outlined in Table II.

Single valves of pelecypods, if unabraded, were probably in situ where collected. Therefore, their use is valid in determining the depth range of the biotopes. Reference to Table II shows that, in general, the depth range for most biotopes is not altered by the addition of single-valve-only occurrences. Only for Biotopes 5 and 10 is there an appreciable extension of the lower limit. In the case of Biotope 5 the lower limit based on complete shells represents a considerable extension of the lower limit of the index species, *Cyclocardia borealis*. For stations with only single valves of *C. borealis* similarity of assemblages was also considered in assigning them to Biotope 5. Thus, the lower limit of 230 m would seem to be valid for this biotope. The lower limit of 256 m for Biotope 10 is well within the depth range of the index species.

As a rule, deposit feeders are most abundant in fine-grained sediments in quiet waters and suspension feeders are characteristic of coarse-grained sediments under more agitated conditions and also of hard substrates (Stanley 1970). In the Bay of Fundy—Gulf of Maine area the biotopes and their index species, for the most part, conform to this pattern.

In conclusion, analysis of the molluscan faunas indicates 10 biotopes, each characterized by an index species and a distinctive suite of accessory species. Each biotope is a mappable entity (Fig 2) with definite depth range and substrate relation-

ships. The 7 biotopes with index species that are suspension feeders are associated primarily with coarse and/or hard substrates and areas of pronounced current action. Those biotopes characterized by deposit feeding index species relate, in general, to finer sediments and quieter waters.

References

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* Key reference for faunal reference list and for depth ranges of index species.

Appendix: Faunal Reference List

Gastropoda

- Acirsa costulata* (Mighels and Adams)—Morris, 1973, pl. 44, fig. 6
= *Turritella costulata* Mighels and Adams, 1842, Boston Jour. Nat. Hist., vol. 4, p. 50, pl. 4, fig. 20.
- Admete couthouyi* (Jay)—Abbott, 1974, p. 248, fig. 2705
= *Cancellaria couthouyi* Jay, 1839, A catalogue of shells in the collection of John C. Jay, M.D., with descriptions, edition 3, p. 77.
- Alvania carinata* Mighels and Adams—Morris, 1973, p. 136, pl. 38, fig. 13
= *A. carinata* Mighels and Adams, 1842, Boston Jour. Nat. Hist., vol. 4, p. 49.
- Alvania janmayeni* (Friele)—Macpherson, 1971, p. 38, pl. 2, fig. 11
= *Rissoa Jan Mayeni* Friele, 1878, Nyt. Mag. f. Naturvid., vol. 24, no. 3, p. 224, pl. 1, figs. 4a, b.
- Anachis avara* (Say)—Abbott, 1974, p. 195, fig. 2049
= *Columbella avara* Say, 1822, Jour. Acad. Nat. Sci., Philadelphia, vol. 2, p. 230.

- Aporrhais occidentalis* (Beck)—Abbott, 1974, p. 143, fig. 1576
= *Rostellaria occidentalis* Beck, 1836, Mag. de Zool., vol. 6, classe 5, pl. 72 and text.
- Boreotrophon clathratus* (Linné)—Abbott, 1974, p. 189, fig. 1971
= *Murex clathratus* Linné, 1767, Syst. Nat., ed. 12, vol. 1, p. 1223.
- Buccinum ciliatum* (Fabricius)—MacGinitie, 1959, p. 113, pl. 10, figs. 8, 9.
= *Tritonium ciliatum* Fabricius, 1780, Fauna Gron., p. 401.
- Buccinum undatum* Linné—Abbott, 1974, p. 203, fig. 2188
= *B. undatum* Linné, 1758, Syst. Nat., ed. 10, p. 740.
- Calliostoma occidentale* (Mighels and Adams)—Abbott, 1974, p. 42, fig. 305
= *Trochus occidentalis* Mighels and Adams, 1842, Boston Jour. Nat. Hist., vol. 4, p. 47.
- Cingula aculeus* (Gould)—Abbott, 1974, p. 74, fig. 652
= *Rissoa aculeus* Gould, 1841, Rept. Invert. Massachusetts, ed. 1, p. 266.
- Colus pubescens* (Verrill)—Abbott, 1974, p. 208, fig. 2284
= *Sipho pubescens* Verrill, 1882, Trans. Connecticut Acad., vol. 5, p. 501, pl. 43, fig. 6, pl. 57, fig. 25.
- Colus pygmaeus* (Gould)—Abbott, 1974, p. 209, fig. 2286
= *Sipho pygmaeus* Gould, 1841, Rept. Invert. Massachusetts, ed. 1, p. 284.
- Colus spitzbergensis* (Reeve)—Abbott, 1974, p. 209, fig. 2288
= *Fusus spitzbergensis* Reeve, 1855, in Belcher, Last of the Arctic voyages 2, Appendix, p. 395, pl. 32, fig. 6.
- Colus stimpsoni* (Mörch)—Abbott, 1974, p. 208, fig. 2283
= *Fusus stimpsoni* Mörch, 1867, Vid. Medd. Natur. Foren., p. 83.
- Crucibulum striatum* (Say)—Abbott, 1974, p. 140, fig. 1548
= *Calyptraea striatum* Say, 1826, Jour. Acad. Nat. Sci., Philadelphia, vol. 5, p. 216.
- Cylichna alba* Brown—Morris, 1973, p. 269, pl. 73, fig. 7
= *C. alba* Brown, 1827, Illustr. Conch. Great Britain, p. 3, pl. 19, figs. 43, 44.
- Epitonium greenlandicum* (Perry)—Abbott, 1974, p. 121, fig. 1247
= *Scalaria greenlandica* Perry, 1811, Conchology, app., pl. 28, fig. 8.
- Haminoea solitaria* (Say)—Abbott, 1974, p. 320, fig. 4017
= *Bulla solitaria* Say, 1822, Jour. Acad. Nat. Sci., Philadelphia, vol. 2, p. 245.
- Hydrobia totteni* Morrison—Abbott, 1974, p. 79, fig. 716
= *H. totteni* Morrison, 1954 (previously known as *H. minuta*)
- Lepeta caeca* (Müller)—Abbott, 1974, p. 34, fig. 186
= *Patella caeca* Müller, 1776, Zoologicae, Danicae prodromus, p. 237.
- Limacina lesueurii* (d'Orbigny)—Abbott, 1974, p. 324, fig. 4045
= *Atlanta lesueurii* d'Orbigny, 1836, Voyage ed Amérique méridionale, vol. 5, p. 177, pl. 20, figs. 12-15.
- Lischkeia ottoii* (Philippi)—Abbott, 1974, p. 39, fig. 265
= *Trochus ottoii* Philippi, 1844, Enum. Moll. Siciliae, vol. 2, p. 227, pl. xxviii, fig. 9.
- Littorina littorea* Linné—Abbott, 1974, p. 67, fig. 549
= *L. littorea* Linné, 1758, Syst. Nat., ed. 10, p. 761.
- Lunatia pallida* (Broderip and Sowerby)—Abbott, 1974, p. 156, fig. 1693
= *Natica pallida* Broderip and Sowerby, 1829, Zool. Jour., vol. 4, pt. 15, p. 372.
- Lunatia triseriata* (Say)—Abbott, 1974, p. 156, fig. 1691
= *Natica triseriata* Say, 1826, Jour. Nat. Sci., Philadelphia, vol. 5, p. 209.
- Margarites costalis* (Gould)—Abbott, 1974, p. 36, fig. 212
= *Trochus costalis* Gould, 1841, Rept. Invert. Massachusetts, p. 252.
- Margarites groenlandicus* (Gmelin)—Abbott, 1974, p. 36, fig. 215
= *Trochus groenlandicus* Gmelin, 1791, Syst. Nat., ed. 13, p. 3574.

- Moelleria costulata* (Möller)—Abbott, 1974, p. 61, fig. 501
 = *Margarita costulata* Möller, 1842, Naturhist, Tidsskrift., ser. 1, vol. 4, p. 81.
- Nassarius trivittatus* (Say)—Abbott, 1974, p. 224, fig. 2459
 = *Nassa trivittata* Say, 1822, Jour. Acad. Nat. Sci., Philadelphia, vol. 2, p. 231.
- Natica clausa* Broderip and Sowerby—Abbott, 1974, p. 159, fig. 1718
 = *N. clausa* Broderip and Sowerby, 1829, Zool. Jour., pt. 15, p. 372.
- Neptunea decemcostata* (Say)—Abbott, 1974, p. 213, Color pl. 12, fig. 2354
 = *Fusus decemcostatus* Say, 1826, Jour. Acad. Nat. Sci., Philadelphia, vol. 5, p. 214.
- Neptunea despecta* (Linné)—Abbott, 1974, p. 213, fig. 2359
 = *Murex despectus* Linné, 1758, Syst. Nat., ed. 10, p. 754.
- Oenopota declivis* (Lovén)—Macpherson, 1971, p. 115, pl. 7, fig. 10
 = *Tritonium declive* Lovén, 1846, Kongl, Svenska Vetensk-Akad. Forhandl., vol. 3, p. 13.
- Oenopota harpularia* (Couthouy)—Abbott, 1974, p. 286, fig. 3386
 = *Fusus harpularia* Couthouy, 1838, Boston Jour. Nat. Hist., vol. 2, pt. 1, p. 106, pl. 1, fig. 10.
- Propebela cancellata* (Mighels and Adams)—Abbott, 1974, p. 284, fig. 3316
 = *Fusus cancellatus* Mighels and Adams, 1842, Boston Jour. Nat. Hist., vol. 4, p. 52, pl. 4, fig. 18.
- Propebela turricula* (Montagu)—Abbott, 1974, p. 284, fig. 3315
 = *Murex turricula* Montagu, 1803, Testacea Britannica, ed. 1, vol. 2, p. 262, pl. 9, fig. 1.
- Puncturella noachina* (Linné)—Abbott, 1974, p. 22, fig. 57
 = *Patella noachina* Linné, 1771, Mantissa plantarum altera generum editionis VI et specierum editionis II. Addendum, p. 551.
- Retusa obtusa* (Montagu)—Abbott, 1974, p. 321, fig. 4024
 = *Bulla obtusa* Montagu, 1808, Testacea Britannica, vol. 1, p. 223.
- Scaphander punctostriatus* Mighels—Abbott, 1974, p. 315, fig. 3954
 = *S. punctostriatus* Mighels, 1841, Proc. Boston Soc. Nat. Hist., vol. 1, p. 49.
- Skeneopsis planorbis* (Fabricius)—Abbott, 1974, p. 81, fig. 735
 = *Helix* (?) *planorbis* Fabricius, 1780, Fauna Groenlandica, p. 394.
- Solariella obscura* (Couthouy)—Abbott, 1974, p. 40, fig. 271
 = *Turbo obscurus* Couthouy, 1838, Boston Jour. Nat. Hist., vol. 2, no. 1, p. 100, pl. 3, fig. 12.
- Solariella varicosa* (Mighels and Adams)—Abbott, 1974, p. 41, fig. 276
 = *Margarita varicosa* Mighels and Adams, 1842, Boston Jour. Nat. Hist., vol. 4, p. 46.
- Tachyrhynchus erosus* (Couthouy)—Abbott, 1974, p. 94, fig. 896
 = *Turritella erosa* Couthouy, 1838, Boston Jour. Nat. Hist., vol. 2, no. 1, p. 103, pl. 3, fig. 1.
- Trichotropis borealis* Broderip and Sowerby—Abbott, 1974, p. 138, fig. 1518
 = *T. borealis* Broderip and Sowerby, 1829, Zool. Jour., vol. 4, pt. 15, p. 375.
- Turbonilla interrupta* (Totten)—Abbott, 1974, p. 305, fig. 3754
 = *Turritella interrupta* Totten, 1835, Amer. Jour. Sci., 1st ser., vol. 28, p. 352.
- Turritelopsis acicula* (Stimpson)—Richards, 1962, p. 77, pl. 15, fig. 34 (as *Turritella* (*Turritelopsis*) *acicula*)
 = *Turritella acicula* Stimpson, 1851, Proc. Boston Soc. Nat. Hist., vol. 4, p. 15.
- Velutina undata* Brown—Abbott, 1974, p. 146, fig. 1604
 = *V. undata* Brown, 1839, Mem. Wernierian Nat. Hist. Soc., Edinburgh, vol. 8, p. 102, pl. 1, fig. 15.

- Velutina velutina* (Müller)—Abbott, 1974, p. 146, fig. 1602
 = *Bulla velutina* Müller, 1776, *Zoologicae Danicae prodromus*, p. 242.

PELECYPODA

- Anomia simplex* d'Orbigny—Abbott, 1974, p. 451, Color pl. 20, fig. 5232
 = *A. simplex* d'Orbigny, 1845, *Moll. Cubana*, vol. 2, p. 367, pl. 38, figs. 31-33.
- Anomia squamula* Linné—Abbott, 1974, p. 452, fig. 5236
 = *A. squamula* Linné, 1758, *Syst. Nat.*, ed. 10, p. 1131.
- Arctica islandica* (Linné)—Abbott, 1974, p. 518, fig. 5823
 = *Venus islandica* Linné, 1758, *Syst. Nat.*, ed. 10, p. 1131.
- Astarte borealis* Schumacher—Abbott, 1974, p. 480, fig. 5515
 = *A. borealis* Schumacher, 1817, *Essai d'un nouveau systeme des habitations des Vers testaces*, p. 47, pl. 17, fig. 1.
- Astarte castanea* (Say)—Abbott, 1974, p. 481, fig. 5522
 = *Venus castanea* Say, 1822, *Jour. Acad. Nat. Sci., Philadelphia*, vol. 4, p. 273.
- Astarte striata* (Leach)—MacGinitie, 1959, p. 167, pl. 22, figs. 14-16
 = *Nicania striata* Leach, 1819, *Ross's Voyage*, Appendix 2, p. 176.
- Astarte subaequilatera* Sowerby—Abbott, 1974, p. 480, fig. 5517
 = *A. subaequilatera* Sowerby, 1854, *Thes. Conch.*, vol. 2, no. 2, p. 36.
- Astarte undata* Gould—Abbott, 1974, p. 480, fig. 5519
 = *A. undata* Gould, 1841, *Rept. Invert. Massachusetts*, p. 80.
- Axinopsida orbiculata* (Sars)—MacGinitie, 1959, p. 172, pl. 20, fig. 2
 = *Axinopsis orbiculata* Sars, 1878, *Mollusca regionis arcticae Norvegiae*, p. 63, pl. 19, figs. 11a-d.
- Bathyarca pectunculoides* (Scacchi)—Abbott, 1974, p. 424, fig. 4990
 = *Arca pectunculoides* Scacchi, 1833, *Sc. Ann. Civ. duc Sic.*, vol. 7, p. 82.
- Cerastoderma pinnulatum* (Conrad)—Abbott, 1974, p. 488, fig. 5586
 = *Cardium pinnulatum* Conrad, 1831, *Jour. Acad. Nat. Sci., Philadelphia*, vol. 6, p. 260, pl. 11, fig. 8.
- Chlamys islandica* (Müller)—Abbott, 1974, p. 444, Colour pl. 19, fig. 5147
 = *Pecten islandicus* Müller, 1776, *Zoologicae Danicae prodromus*, p. 248.
- Clinocardium ciliatum* (Fabricius)—Abbott, 1974, p. 487, fig. 5583
 = *Cardium ciliatum* Fabricius, 1780, *Fauna Gronl.*, p. 410.
- Crassostrea virginica* (Gmelin)—Abbott, 1974, p. 456, fig. 5274
 = *Ostrea virginica* Gmelin, 1790, *Syst. Nat.*, ed. 13, vol. 1, pt. 6, p. 3336.
- Crenella decussata* (Montagu)—Abbott, 1974, p. 430, fig. 5052
 = *Mytilus decussatus* Montagu, 1808, *Testacea Britannica*, suppl., p. 69.
- Crenella faba* (Müller)—Abbott, 1974, p. 431, fig. 5054
 = *Mytilus faba* Müller, 1776, *Zoologicae Danicae prodromus*, p. 250.
- Crenella glandula* Totten—Abbott, 1974, p. 430, fig. 5051
 = *C. glandula* Totten, 1834, *American Jour. Sci.*, vol. 26, p. 367.
- Cyclocardia borealis* (Conrad)—Abbott, 1974, p. 478, fig. 5493
 = *Cardita borealis* Conrad, 1831, *American Marine Conchol.*, p. 39.
- Cyclopecten pustulosus* (Verrill)—Abbott, 1974, p. 445, fig. 5160
 = *Pecten pustulosus* Verrill, 1873, *American Jour. Sci.*, vol. 5, p. 14.
- Dacrydium vitreum* (Holböll)—Abbott, 1974, p. 436, fig. 5102
 = ?*Mytilus vitrea* Holböll, in Moller, 1842, *Naturhist. Tidsskrift*, vol. 4, no. 1, p. 92.
- Delectopecten vitreus* (Gmelin)—Abbott, 1974, p. 446, fig. 5173
 = *Pecten vitreus* Gmelin, 1791, *Syst. Nat.*, vol. 1, p. 3228 (?).

- Ensis directus* (Conrad)—Abbott, 1974, p. 494, fig. 5627
= *Solen directus* Conrad, 1843, Proc. Acad. Nat. Sci., Philadelphia, vol. 1, p. 325.
- Hiatella arctica* (Linné)—Abbott, 1974, p. 541, fig. 6019
= *Mya arctica* Linné, 1767, Syst. Nat., ed. 12, p. 1113.
- Limopsis minuta* (Philippi)—Abbott, 1974, p. 425, fig. 5001
= *Pectunculus (Limopsis) minutus* Philippi, 1836, Enum. Moll. Siciliae, vol. 1, p. 63, pl. 5, fig. 3.
- Liocyma fluctuosa* (Gould)—Abbott, 1974, p. 528, fig. 5906
= *Venus fluctuosa* Gould, 1841, Rept. Invert. Massachusetts, p. 87, fig. 50.
- Lucinoma filosa* (Stimpson)—Abbott, 1974, p. 461, fig. 5325
= *Lucina filosa* Stimpson, 1851, Shells of New England, vol. A7, no description.
- Lyonsia hyalina* (Conrad)—Abbott, 1974, p. 554, fig. 6078
= *Mya hyalina* Conrad, 1831, Jour. Acad. Nat. Sci., Philadelphia, vol. 6, p. 261, pl. 11, fig. 12.
- Macoma calcaria* (Gmelin)—Abbott, 1974, p. 505, fig. 5711
= *Tellina calcaria* Gmelin, 1791, Syst. Nat., ed. 13, vol. 1, pt. 6, p. 3236.
- Megayoldia thraciaeformis* (Storer)—Abbott, 1974, p. 418, fig. 4918
= *Nucula thraciaeformis* Storer, 1838, Boston Jour. Nat. Hist., vol. 2, p. 122.
- Mercenaria mercenaria* (Linné)—Abbott, 1974, p. 523, fig. 5861
= *Venus mercenaria* Linné, 1758, Syst. Nat., ed. 10, p. 686.
- Mesodesma arctatum* (Conrad)—Morris, 1973, p. 72, pl. 27, fig. 12
= *Mactra arctata* Conrad, 1830, Jour. Acad. Nat. Sci., Philadelphia, vol. 6, p. 257, pl. 11, fig. 1.
- Modiolus modiolus* (Linné)—Abbott, 1974, p. 434, fig. 5088
= *Mytilus modiolus* Linné, 1758, Syst. Nat., ed. 10, p. 706.
- Musculus discors* (Linné)—Abbott, 1974, p. 432, fig. 5065
= *Mytilus discors* Linné, 1767, Syst. Nat., ed. 12, p. 1159.
- Musculus niger* (Gray)—Abbott, 1974, p. 432, fig. 5064
= *Modiola nigra* Gray, 1824, Parry's first voyage, 1819-20, suppl. to appendix, p. 244.
- Mya arenaria* Linné—Abbott, 1974, p. 536, fig. 5983
= *M. arenaria* Linné, 1758, Syst. Nat., ed. 10, p. 670.
- Mya truncata* Linné—Abbott, 1974, p. 537, fig. 5984
= *M. truncata* Linné, 1758, Syst. Nat., ed. 10, p. 670.
- Nucula delphinodonta* Mighels and Adams—Abbott, 1974, p. 410, fig. 4793
= *N. delphinodonta* Mighels and Adams, 1842, Boston Jour. Nat. Hist., vol. 4, p. 40.
- Nucula proxima* Say—Abbott, 1974, p. 410, fig. 4786
= *N. proxima* Say, 1820, American Jour. Sci., ser. 1, vol. 2, p. 40.
- Nucula tenuis* (Montagu)—Abbott, 1974, p. 411, fig. 4794
= *Arca tenuis* Montagu, 1808, Testacea Britannica, suppl., p. 56, pl. 29, fig. 1.
- Nuculana messanensis* (Seguenza)—Abbott, 1974, p. 414, fig. 4853
= *Leda messanensis* Seguenza, 1877, Accad. Lincei, Atti, ser. 3, vol. 1, p. 1175, pl. 3, figs. 15, 15a, 15e.
- Nuculana minuta* (Fabricius)—Morris, 1973, p. 5, pl. 9, fig. 12
= *Arca minuta* Fabricius, 1776, Fauna Gronl., p. 414.
- Nuculana pernula* (Müller)—Abbott, 1974, p. 413, fig. 4848
= *Arca pernula* Müller, 1779, Beschäft. Naturf. Freunde zu Berlin, vol. 4, p. 55.
- Palliolum imbrifer* (Lovén)—Abbott, 1874, p. 446, fig. 5171
= *Pecten imbrifer* Lovén, 1846, Kongl. Svenska Vetensk.-Akad. Forhandl., vol. 3, p. 31.

- Palliolum striatum* (Müller)—Abbott, 1974, p. 446, fig. 5165
 = *Pecten striatus* Müller, 1776, Zoologicae Danicae prodromus, p. 248.
- Palliolum subimbrifer* (Verrill and Bush)—Abbott, 1974, p. 446
 = *Cyclopecten subimbrifer* Verrill and Bush, 1897, Trans. Connecticut Acad., vol. 10, pp. 84, 92.
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 = *P. gouldiana* Dall, 1886, Bull. Mus. Comp. Zool., vol. 12, p. 312.
- Pandora inornata* (Verrill and Bush)—Abbott, 1974, p. 556, fig. 6094
 = *Clidiophora inornata* Verrill and Bush, 1898, Proc. United States Nat. Mus., vol. 20, p. 819, pl. XCV, figs. 5, 6.
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 = *Glycimeris arctica* Lamarck, 1818, Hist. nat. anim. sans vert., vol. 5, p. 458.
- Periploma fragile* (Totten)—Abbott, 1974, p. 560, fig. 6130
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- Placopecten magellanicus* (Gmelin)—Abbott, 1974, p. 448, Colour pl. 18, fig. 5202
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 = *Nucula limatula* Say, 1831, American Conchol., vol. 1, p. 12.
- Yoldia myalis* (Couthouy)—Abbott, 1974, p. 417, fig. 4911
 = *Nucula myalis* Couthouy, 1838, Boston Jour. Nat. Hist., vol. 2, p. 62, pl. 3, fig. 7.
- Yoldia sapotilla* Gould—Abbott, 1974, p. 417, fig. 4910
 = *Y. sapotilla* Gould, 1841, Rept. Invert. Massachusetts, p. 100.
- Yoldiella fraterna* (Verrill and Bush)—Abbott, 1974, p. 419, fig. 4932 (as *Portlandia* (*Yoldiella*) *fraterna*)
 = *Yoldia fraterna* Verrill and Bush, 1898, Proc. United States Nat. Mus., vol. 20, p. 867, pl. LXXX, fig. 5, p. LXXXII, fig. 8.
- Yoldiella frigida* (Torell)—Abbott, 1974, p. 418, fig. 4929 (as *Portlandia* (*Yoldiella*) *frigida*)
 = *Yoldia frigida* Torell, 1859, Spitz. Moll., p. 148, pl. 1, fig. 3.
- Yoldiella inconspicua* Verrill and Bush—Abbott, 1974, p. 419, fig. 4933 (as *Portlandia* (*Yoldiella*) *inconspicua*)
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ZOOPLANKTON STUDIES IN THE SOUTHERN BIGHT OF MINAS BASIN

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Quantitative samples of zooplankton were taken at 20 stations in the southern bight of Minas Basin to investigate spatial and temporal composition and abundance. Dominant forms in spring were the copepod *Eurytemora herdmani*, and nauplii and cypris larvae of *Balanus*. In summer *Acartia tonsa* was most abundant at inshore stations whereas *E. herdmani* was restricted to deeper, cooler water. At times the association was dominated by polychaete trochophores, at others by nematodes. All species had extremely patchy distributions. Estimates of total abundance of zooplankton varied from $< 5,000/m^3$ to $> 450,000/m^3$. Hourly sampling at 3 anchor stations demonstrated considerable asymmetry of plankton composition during ebb and flood tides.

Introduction

The Minas Basin, with its high tidal range and consequent high turbulence and turbidity, is clearly a physically stressed system. Usually physically stressed systems exhibit characteristic biological features: low community diversity coupled (except in cases of extreme pollution) with moderate to high secondary productivity, limited primary productivity, and a faunal association adapted to utilisation of allochthonous energy. Not all of these features, however, appear to apply to the Minas Basin. Bousfield and Leim (1960) recorded rather large numbers of benthic and nektonic animals in Minas Basin, several of which were considered endemic to the region. The plankton was not specifically included in that study.

Jermolajev (1958), however, examined plankton samples taken by 2 different expeditions up the Bay of Fundy and noted that the inner Bay was "practically devoid of locally produced zooplankton", but that Minas Basin had regions inhabited by endemic estuarine forms. Her results indicated rather large numbers of *Pseudodiaptomus coronatus* and *Acartia tonsa* in Cobequid Bay and a paucity of larger forms typical of the outer Bay of Fundy and Gulf of Maine. Although she did not study production, Jermolajev noted that *Calanus finmarchicus* accidentally carried into Minas Basin rapidly lost their oil reserves and appeared in poor condition and attributed this to the lack of phytoplankton consequent upon high turbidity.

The present study was initiated to examine the composition of the plankton in the southern bight of Minas Basin, a region that exhibits considerable heterogeneity of benthic communities, an extensive fringe of saltmarsh, and a highly variable turbidity. Emphasis has been placed upon the important relationships of zooplankton with suspended particulate matter and with predators, particularly fish larvae. This paper presents a first account of the composition, distribution, and tidal movements of zooplankton in the southern bight of Minas Basin. Our primary objective in this presentation is to demonstrate some of the basic temporal and spatial patterns exhibited by zooplankton populations in inner regions of the Bay of Fundy. The long term objective is to evaluate the role of the zooplankton in the Minas Basin system so that more realistic predictions might be made of the effects of any

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development that would modify tidal movements and hence the turbulence and turbidity of the water.

Methods

Plankton samples were taken within 1.5 h of high tide at 20 locations between 17 May and 3 August 1978 in association with other physical and chemical studies. Location of sample sites and an account of physical features of the southern bight region are given in Daborn and Pennachetti (1979). At each site 3 vertical tows were taken from 0.5 m above the bottom to the surface using either a Wisconsin net with 15 cm aperture and 80 μm mesh or a conical net with 30 cm aperture and 64 μm mesh. Survey samples were returned to the laboratory and fixed with 5% neutral seawater-formalin.

In conjunction with time-depth studies of physical parameters, vertical plankton tows were also taken at hourly intervals from one high tide to the next at 3 anchor stations. Locations of the anchor stations are given in Daborn and Pennachetti (1979). Three vertical hauls were taken at each hour using the 30 cm-64 μm conical net, combined into a single sample, and immediately fixed. The net was weighted to reduce drag, but during maximum ebb and flood oblique tows were unavoidable. Length of tow rope was recorded, and in making estimates of total abundance it has been assumed that sampling was 100% efficient. Of necessity, we have also assumed that the water was not moving during retrieval of nets, and therefore that volume sampled is a function solely of net aperture and distance towed. This was a reasonable assumption for samples taken at slack water.

Large zooplankters ($> 2\text{mm}$) were enumerated and removed from whole samples. Sample volume was then made up to 400 ml, and smaller zooplankters were examined and counted in 2 to 5 1-ml subsamples removed by syringe and ejected into a Sedwick-Rafter Counting Cell. Following examination subsamples were returned to the original container and the sample re-examined by a separate individual to avoid subsampling bias. Data presented are based on averages of all sub-samples taken.

Results

Composition of the Plankton

The organisms captured in plankton samples varied widely in both time and space. A complete list of those for which at least generic identification was possible (and excluding fish larvae) is given in Table I. Many other taxa that could not be identified satisfactorily were present, and some of these, notably nematodes, polychaete trochophores, and decapod larvae, were very important components of some samples.

It is convenient to recognise 3 major categories of plankton organisms (Table I): i) the *holoplankton* includes species with an entirely planktonic life history; ii) the *tychoplankton* consists of species that alternate between pelagic and benthic modes of behavior with apparent ease, and iii) the *meroplankton*, species of which are temporary members of the plankton only. The last category includes larval stages of benthic animals, reproductive stolons of benthic polychaetes, or poorly swimming larvae of chordates (Perkins 1974). All of the above are species that are resident in a given body of water (i.e. are autochthonous). In estuaries a fourth group is often encountered composed of allochthonous organisms derived from other regions.

The major holoplanktonic members of the plankton were several copepods, par-

Table I. Taxa* identified in plankton hauls from the southern bight of Minas Basin, 1978.

		Status**
PROTOZOA	<i>Ceratium</i> sp.	I
	<i>Tintinnopsis</i> sp.	I
CNIDARIA	<i>Bougainvillia</i> sp.	II
	<i>Nemopsis bachei</i> Agassiz	II
	<i>Nematostella vectensis</i> Stephanson	II
CTENOPHORA	<i>Pleurobrachia pileus</i> (Fabricius)	I
MOLLUSCA	<i>Nassarius obsoleta</i> (Say)***	II
ANNELIDA	<i>Autolytus cornutus</i> Agassiz	II
	<i>Tharyx acutus</i> Webster & Benedict	II
	<i>Streblospio</i> sp.	II
	<i>Pygospio</i> sp.	II
ARTHROPODA	<i>Podon leuckarti</i> Sars	I
	<i>Eurytemora herdmani</i> Thompson & Scott	I
	<i>Centropages hamatus</i> (Lilljeborg	I
	<i>Acartia tonsa</i> Dana	I
	<i>Pseudodiaptomus coronatus</i> Williams	I
	<i>Calanus finmarchicus</i> (Gunner)	I IV
	<i>Caligus rufimaculatus</i> Wilson	
	<i>Parathalestris croni</i> (Krøyer)	I
	<i>Idotea baltica</i> (Pallas)	III
	<i>Amphithoe rubricata</i> Mont.	III
	<i>Corophium volutator</i> (Pallas)	III
	<i>Caprella linearis</i> (L.)	III
	<i>Balanus balanoides</i> L.	II (IV?)
	<i>Neomysis americana</i> (Smith)	III
CHAETOGNATHA	<i>Sagitta elegans</i> Verrill	I IV

* excluding fish larvae

**I - Holoplankton

II - Meroplankton

III - Tychoplankton

IV - Allochthonous species

*** egg stage identified

ticularly *Eurytemora herdmani* and *Acartia tonsa*. These 2 species are common dominants in brackish, turbid waters (Wilson 1932) and have been recorded previously from Minas Basin (Jermolajev 1958) and other estuaries in Atlantic Canada (Shih et al. 1971). *Pseudodiaptomus coronatus*, another typically brackish-water species, was infrequently collected during this study. Jermolajev (1958), however, noted that it occurred in very large numbers in Cobequid Bay during July 1951, and was present in the southern bight of Minas Basin in September 1920. Our results indicate that the species is not abundant in the southern bight; individuals collected there might have originated in Cobequid Bay. It is a dominant species in Cumberland Basin (unpubl.). *Centropages hamatus* was occasionally collected in the southern bight, but never in numbers comparable to those of *E. herdmani* or *A. tonsa*. It is very common in the main part of the Bay of Fundy (Jermolajev 1958), in Chignecto Bay, and in Shepody Bay (unpubl.). The harpacticoid copepod, *Parathalestris (Halithalestris) croni*, was an abundant and regular member of the plankton. Unlike many other harpacticoids, this species is habitually pelagic, occurring in surface waters both inshore and offshore (Wilson 1932), and is a common resident of estuaries in the region (Shih et al. 1971). It probably breeds successfully in the southern bight.

The remaining copepods, *Calanus finmarchicus* and *Caligus rufimaculatus*, are probably allochthonous, derived from populations resident in the Bay of Fundy. Indeed, there is considerable evidence that *C. finmarchicus* is unable to maintain breeding populations within the Bay of Fundy itself, and arrives there only as copepodite stages from the Gulf of Maine (Fish & Johnson 1937; Huntsman 1952; Jermolajev 1958). Our recent studies (unpubl.) have confirmed that the *Calanus* encountered in Chignecto Bay are nearly always CIII - CV copepodites. *Caligus* has been collected only twice in Minas Basin.

Meroplanktonic species in these collections are difficult to identify with certainty, except for *Autolytus cornutus*, the reproductive stolons of which were common in May and June. This species is important in Chignecto Bay (unpubl.), and has been recorded elsewhere in the Bay of Fundy (Fish & Johnson 1937). Polychaete and pelecypod trochophores and gastropod veliger larvae were abundant, even dominant components at times throughout the summer. Specific identification was impossible, but the important species undoubtedly are the same as those that dominate the benthos (cf. McCurdy 1979). Often, however, the major components of plankton samples were nauplii and cypris larvae of barnacles—most probably *Balanus balanoides*, the most abundant barnacle species in southern Minas Basin (Bousfield & Leim 1960). In the southern Minas Basin only the Blomidon region has stable rock substrates where *Balanus* might overwinter, thus many of these larvae were probably spawned a considerable distance away.

Benthic animals occasionally appearing in plankton samples included young of the very important amphipod *Corophium volutator* and occasional *Amphithoe*, *Idotea*, and *Caprella*. *Neomysis americana*, which is relatively abundant in night tows in Cumberland Basin (unpubl.), was encountered occasionally in daytime samples from the southern bight, and may have proved more abundant in night tows.

The plankton of the southern bight of Minas Basin is thus considerably more diverse than might be deduced from Jermolajev's (1958) account. Two species are recorded here (Table I) apparently for the first time: the ctenophore *Pleurobrachia pileus* and the cladoceran *Podon leuckarti*. The former species was occasionally fairly numerous. As yet, however, only 1 species in the plankton appears to be endemic (sensu stricto) to the Minas Basin, namely a new species of the anthomedusan *Bougainvillia*. This is in marked contrast to the high degree of endemism found among benthic forms (Bousfield & Leim 1960; Bleakney, in verb.).

Regional and Temporal Variations

Contemporaneous studies of salinity and turbidity indicated that there were marked regional differences within the southern bight itself (Daborn & Pennachetti 1979). Similar regional differences were evident in the relative abundance of zooplankton species, but the pattern was rendered much more complex by temporal changes in relative abundance and distribution (Fig 1).

During May the zooplankton association consisted of < 10 groups of which 3 (copepodites of *E. herdmani* and/or *A. tonsa*, *Balanus* nauplii and polychaete trochophore larvae) usually constituted > 90% of the organisms captured. Nevertheless, regional differences were clearly evident: juvenile copepods were always the most abundant organism in the shallow, extremely turbid waters near the mouths of the Cornwallis and Canard Rivers and Habitant Creek, whereas in deeper waters at the entrance to the southern bight, samples were sometimes dominated by *Balanus* nauplii and cypris larvae. The latter undoubtedly reflect influx of water recently derived from the Bay of Fundy, and settlement of young barnacles on stakes established in the southern bight was noted during early June. Since development from spawning to settlement takes 15 to 20 days (Bousfield 1955), it is possible that parental populations were very distant.

The copepod larvae present in the southern bight in May were not identified. However, *E. herdmani* adults in breeding condition were numerous at shallow stations on 24 May, and subsequently (9 June) large numbers of nauplii were present. At the end of June, however, *A. tonsa* adults and copepodids were also common at inner stations.

Differences in relative abundance, however, occasionally reflected the occurrence of large numbers of a single organism in relatively dense, discrete clouds (e.g. polychaete trochophore larvae at sta. I, 24 May and *Balanus* cypris larvae at sta. M, Q, 17 May; H, Q, 24 May). Polychaete larvae were particularly numerous at inshore stations on 9 June, perhaps the result of local spawning of polychaetes of the Starr's Point and Kingsport mudflats. By late June these components of the plankton had declined leaving the association dominated again by immature copepods (particularly nauplii) and nematodes.

On and after 7 July *A. tonsa* CV copepodites and adults (CVI) were more numerous than *E. herdmani* at nearly all stations. These mature and maturing copepods may have been derived from the CI - CIV copepodites so abundant 2 weeks before. Although some of the nauplii of that time resulted from the May-June breeding phase of *E. herdmani*, *A. tonsa* is known to produce resting eggs which might have provided nauplii even though adults were absent. The ability of *A. tonsa* to develop and colonise areas from small, localised sources has been noted before (Jeffries 1962). During August adult and CV *E. herdmani* were apparently absent from all inshore stations (Fig 2), but remained present in moderate numbers at deeper stations near the mouth of the southern bight.

Numerically, nauplii and copepodite stages of *A. tonsa* and *E. herdmani* were the dominant forms in the plankton during the latter part of the summer. On occasion, dense localised aggregations of nematodes or rotifers were encountered—the former primarily at shallower stations and the latter at offshore locations. These events contributed to the patchiness evident in the zooplankton of the southern bight.

The fine mesh sizes used render the vertical tows moderately quantitative only for the smaller organisms such as the copepods (Fig 2). The sample stations have been grouped according to region within the southern bight: those in shallow water locations nearest the river mouths representing the innermost regions (A, B, C, D, I,

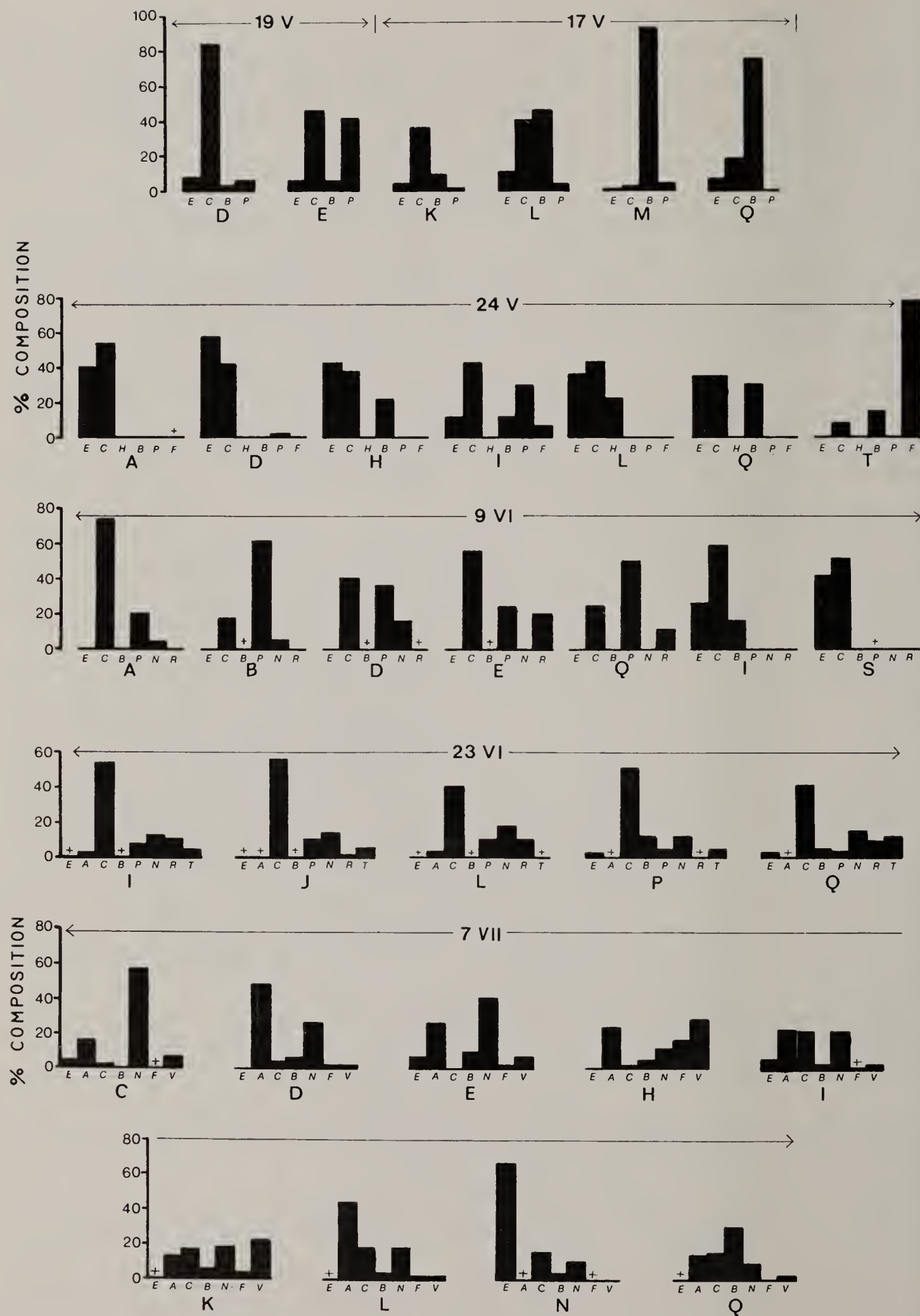


Fig 1. Seasonal and regional variations in percent composition of plankton in the southern bight of Minas Basin, 1978.
A-T Sample stations (cf. Daborn & Pennachetti 1979)
E - *Eurytemora herdmani* CV and CVI; A - *Acartia tonsa* CV and CVI;
c - copepodites I-IV and nauplii 1-6; H - *Parathalestris croni*;

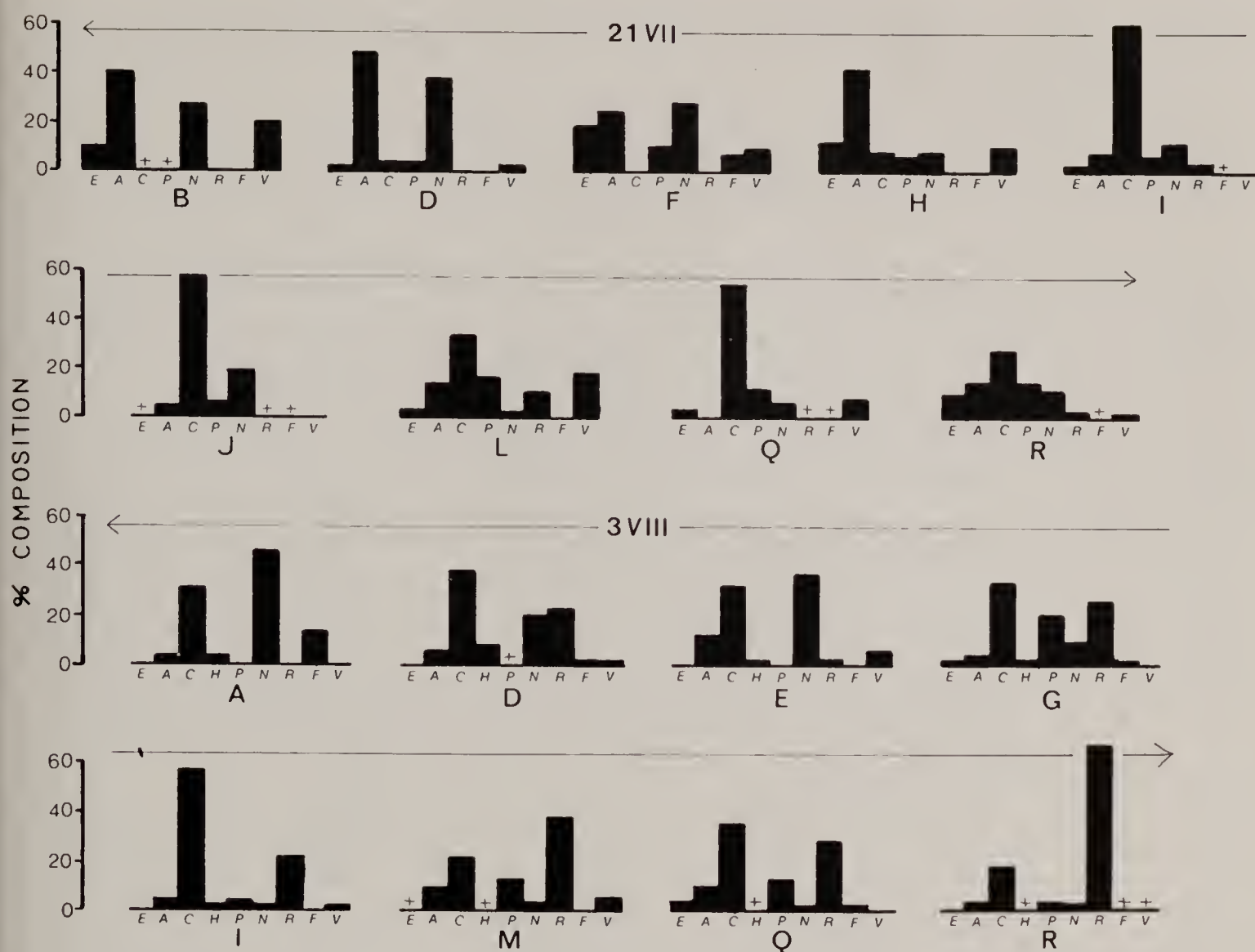


Fig. 1 (cont.)

P - polychaete trochophore and post-trochophore larvae; *N* - nematodes; *R* - rotifers; *F* - Foraminifera; *V* - gastropod veliger larvae; *B* - *Balanus* sp. cypris and nauplius larvae; *T* - Tintinnoidea

L, K); a group of deeper water stations at the entrance to the southern bight (R, N, Q, P); and one intermediate group (E, F, G, H, J, M, S) (cf. Fig 1 Daborn & Pennachetti 1979).

Estimates of copepod abundance varied from < 2000 to $> 84,000/\text{m}^3$ during this regional study. During June and July CV and adult *A. tonsa* were more numerous at the shallow inner stations than at those in deeper water, whereas the reverse was true for *E. herdmani*. In early June numbers of polychaete trochophore larvae varied from $< 1,000$ to $> 68,000/\text{m}^3$, but were generally $< 8,000/\text{m}^3$ at most sites. Nematodes in July and August ranged from $200/\text{m}^3$ to $> 9,000/\text{m}^3$. Unfortunately, quantitative samples were not obtained when the major spawning period of *Balanus* occurred.

Tidal Studies

On 29 May a site on the Starr's Point mudflat near Wolfville (see Daborn & Pennachetti 1979, Fig 1) was sampled from 0800 to 2000 h (Fig 3). As the tide ebbed during the morning, the proportion of adult *E. herdmani* and copepodites declined until, just before the station went dry, the sample was almost all calanoid nauplii and a few harpacticoid copepods (Table II). When the tide returned, it brought with it large numbers of calanoid nauplii (ca. $360,000/\text{m}^3$) and polychaete trochophores, the latter presumably released by polychaetes of the Starr's Point and Kingsport mudflats.

Table II. Abundance of zooplankton during tidal study at Site I (near Wolfville), 29 May 1978.

Number per m ³					
Time	Depth (m)	<i>Eurytemora</i> CV + CVI	Juvenile* Copepods	Polychaeta Trochophores	Total**
0800	6.3	166	13,647	645	15,145
0900	3.0	754	20,371	150	24,899
1000	2.3	539	137,968	5,200	151,441
1100	1.5	0	77,337	860	85,825
1200-1500	DRY — no samples				
1600	1.4	9,431	385,639	3,780	421,270
1700	3.5	1,257	34,581	4,880	44,327
1800	8.0	377	37,726	11,900	50,930
1900	9.0	222	11,872	5,300	19,306
1930	9.3	214	6,752	3,930	13,290

* Including nauplii 1-6 and copepodids I-IV

** Including: Nematoda (<7%), Harpacticoida (<5%), *Balanus* larvae (<5%), Caridea (<1%), Pelecypoda larvae (<1%), Turbellaria (<1%).

Copepods comprised about one-half and polychaete trochophores about one-third of the last samples taken on the evening high tide, with a few nematodes and *Balanus* cypris larvae. The extremely high counts (15,000 to > 420,000/m³) just as water returned on the flood suggests that early copepod nauplii and polychaete trochophores are concentrated near the advancing tide front. However, control of water volume sampled is more difficult on the flood tide than the ebb in shallow waters because of greater turbulence.

Results of the second tidal study on 16 June at Longspell Point (Daborn & Pennachetti 1979, Fig 1), are shown in Figure 4. Sharp changes in composition occurred also at the deeper (<15 m) station. Near the morning high tide tintinnids composed about 50% of the zooplankton, but as the tide ebbed, the proportion declined to <2% at low tide. With the flooding tide, however, the proportion of tintinnids in-

creased steadily once again. Tintinnids were generally much more abundant at the deeper stations.

Total abundance of zooplankton varied much less at this station than during the previous study (Table III). As before, however, these changes largely reflected the patchiness of copepod larvae, polychaete larvae (200-14,000/m³), and the tintinnids. Although the relative abundance of nematodes changed, absolute numbers varied little (ca. 2,000-11,000/m³).

As in the 29 May study, considerable changes occurred in the relative abundance of dominant species over the tidal cycle on 13 July at site 3, despite the greater number of species present at this time in the season. Variations in % composition (Fig 5) primarily reflected fluctuations in the number of *A. tonsa* and juvenile copepods (Table IV), and to a lesser extent, of nematodes (200-56,000/m³). Greatest abundance occurred just before the station went dry, unlike the 29 May study when peak numbers were present after low tide. This difference may be related to tidal asymmetry and variations in the manner in which water flows on the flood and ebb tides. In particular, this station exhibited an anomalous increase in depth during the ebb tide and a corresponding decrease in depth on the flood that we have attributed to sudden changes from sheet to channel flow, and vice versa (Daborn & Pennachetti 1979). Nonetheless, the very considerable changes indicate again that planktonic animals are highly contagiously distributed within the southern bight.

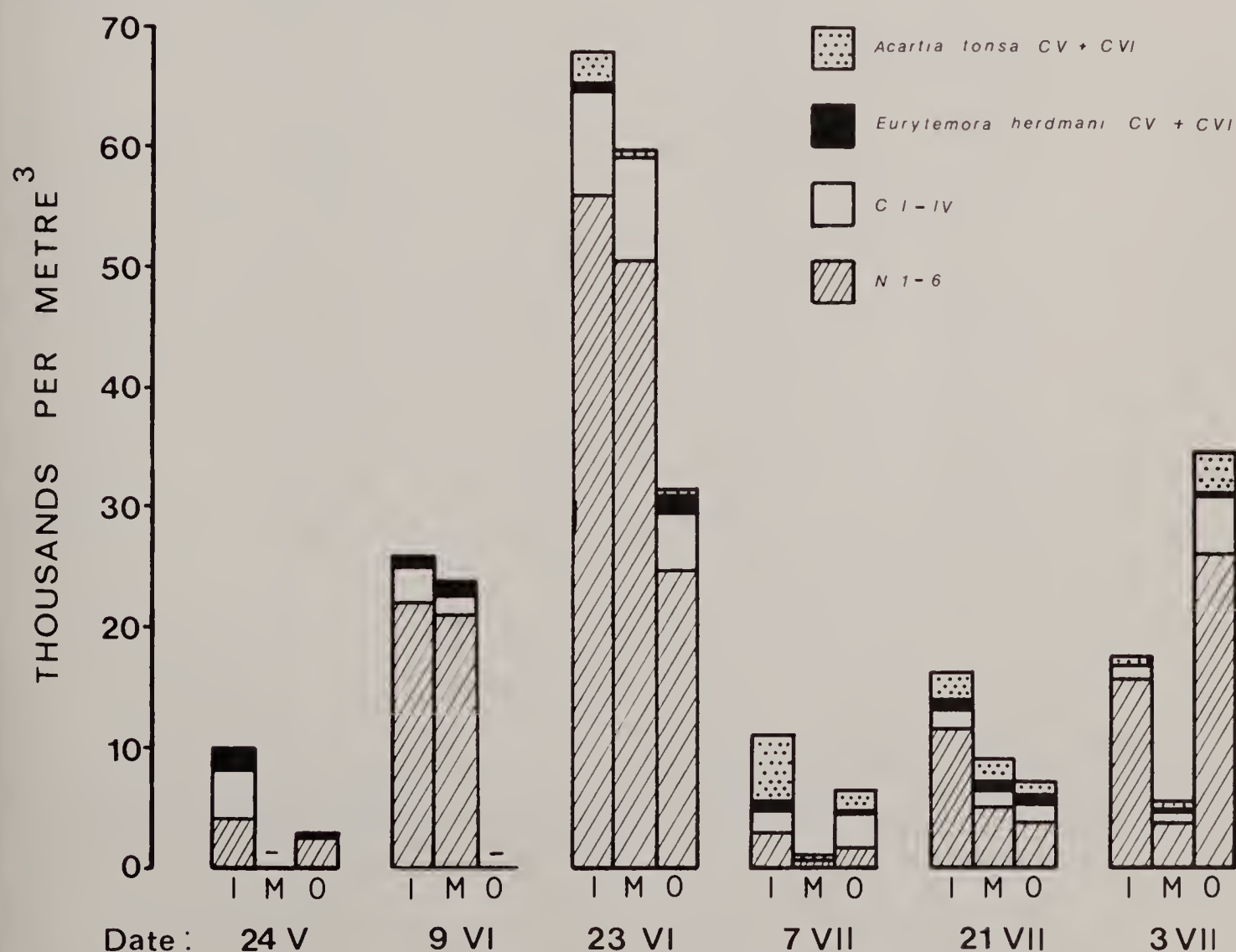


Fig 2. Abundance of copepods in the southern bight of Minas Basin, 1978.

I - inner stations (A,B,C,D,I,L,K)

M - middle stations (E,F,G,H,J,M,S)

O - outer stations (R,N,Q,P)

— no samples taken

Table III. Abundance of zooplankton during tidal study at Site II (Longspell Point), 16 June 1978.

Number per m ³					
Time	Depth (m)	<i>Eurytemora</i> CV + CVI	<i>Acartia</i> CV + CVI	Juvenile* Copepods	Total**
0815	14.8	854	0	5,783	12,948
0915	14.2	1,858	0	7,917	23,062
1015	13.6	5,399	72	14,975	34,702
1115	10.3	1,257	96	9,867	29,697
1215	8.5	354	0	6,956	17,684
1315	5.0	419	0	11,318	33,953
1415	4.5	943	0	28,766	44,318
1515	2.9	393	0	50,694	84,883
1615	4.5	0	0	50,645	103,274
1715	7.0	0	0	15,235	30,325
1815	9.0	311	0	11,429	28,849
1915	12.0	574	0	25,588	46,008
2015	14.0	1,631	0	3,120	21,416

* Including nauplii 1-6 and copepodids I-IV

** Including: Tintinnoidea (<50%), Foraminifera (<8%), Nematoda (<42%), Rotifera (<21%), Polychaeta (<25%), Harpacticoida (<10%), *Balanus* larvae (<6%).

Table IV. Abundance of zooplankton during tidal study at site III (Canard River), 13 July 1978.

Number per m ³					
Time	Depth (m)	<i>Eurytemora</i> CV + CVI	<i>Acartia</i> CV + CVI	Juvenile* Copepods	Total**
0830	6.4	3,837	11,669	22,699	44,440
0930	2.5	1,886	38,197	17,920	62,247
1030***	3.3	12,462	97,008	36,378	176,165
1130	1.0	1,886	241,444	32,067	360,280
1200-1400	Dry — no samples				
1430	2.0	629	15,090	629	40,869
1530	5.3	0	18,077	8,449	43,031
1630	8.5	472	21,456	11,671	43,974
1730***	8.0	3,395	3,521	11,695	27,288
1830	9.8	2,231	2,332	6,085	15,414
1930	11.0	90	5,928	3,323	14,371
2030	10.0	298	3,673	1,986	6,949

* Including nauplii 1-6 and copepodids I-IV

** Including: Tintinnoidea (<2%), Foraminifera (<3%), Nematoda (<51%), Rotifera (<2%), Gastropoda (<3%), Polychaeta (<4%), Harpacticoida (<9%), *Balanus* larvae (<2%).

*** The sudden transient increase in depth on the ebb tide and a similar decrease on the flood tide is attributed to channel effects (see Daborn & Pennachetti 1979).

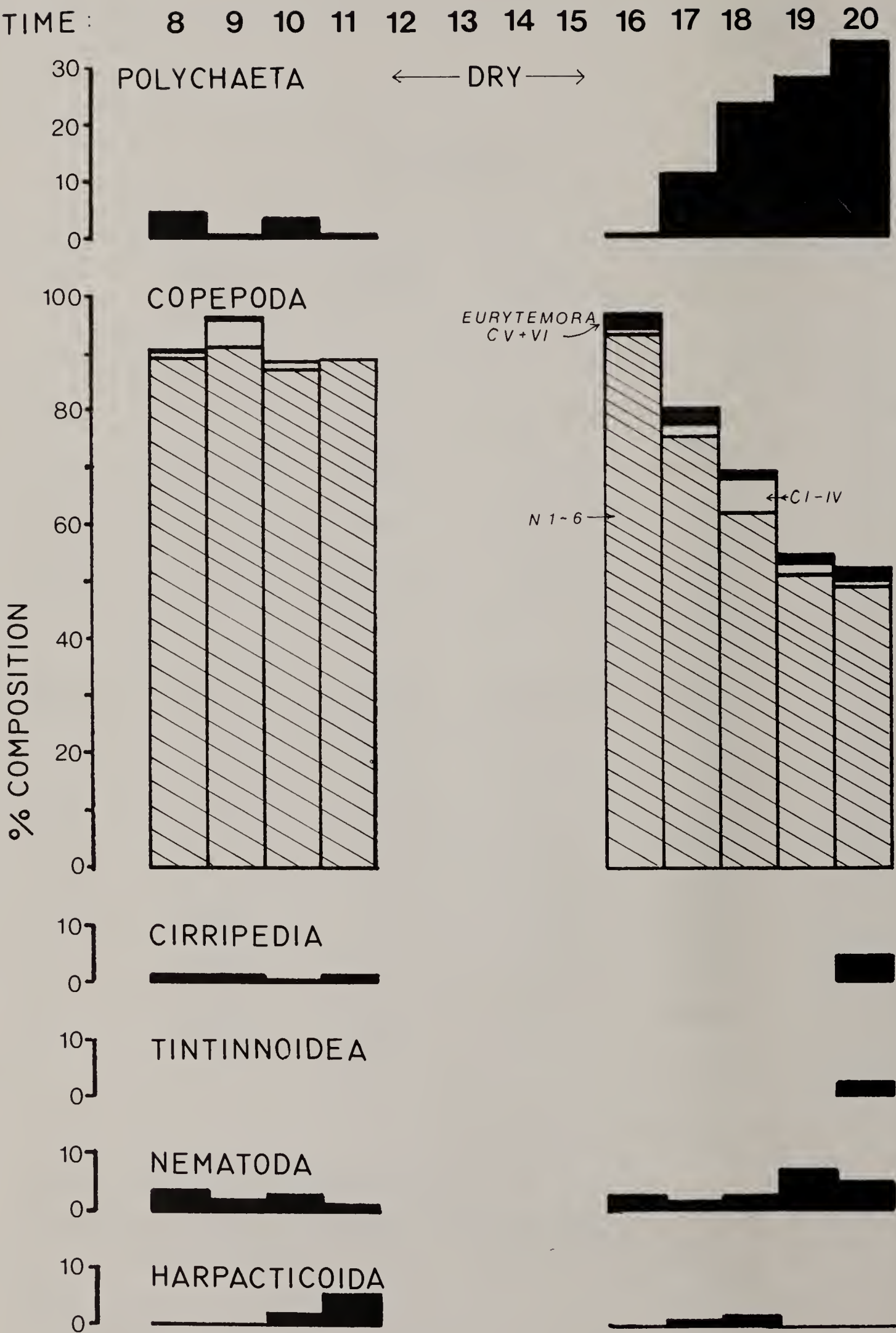


Fig 3. Hourly changes in percent composition of zooplankton at site I (Wolfville), 29 May 1978.

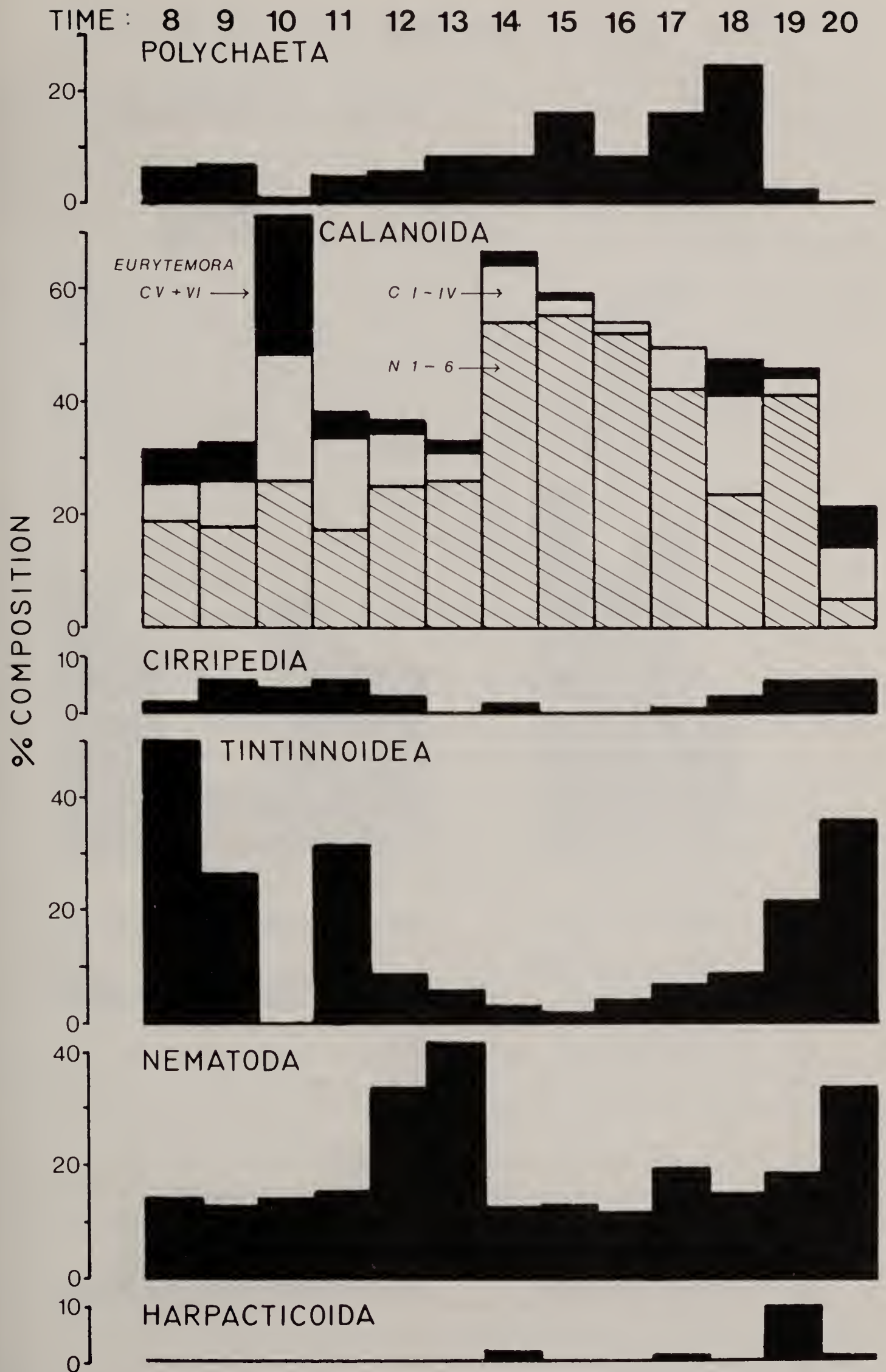


Fig 4. Hourly changes in percent composition of zooplankton at site II (Longspell Point), 16 June 1978.

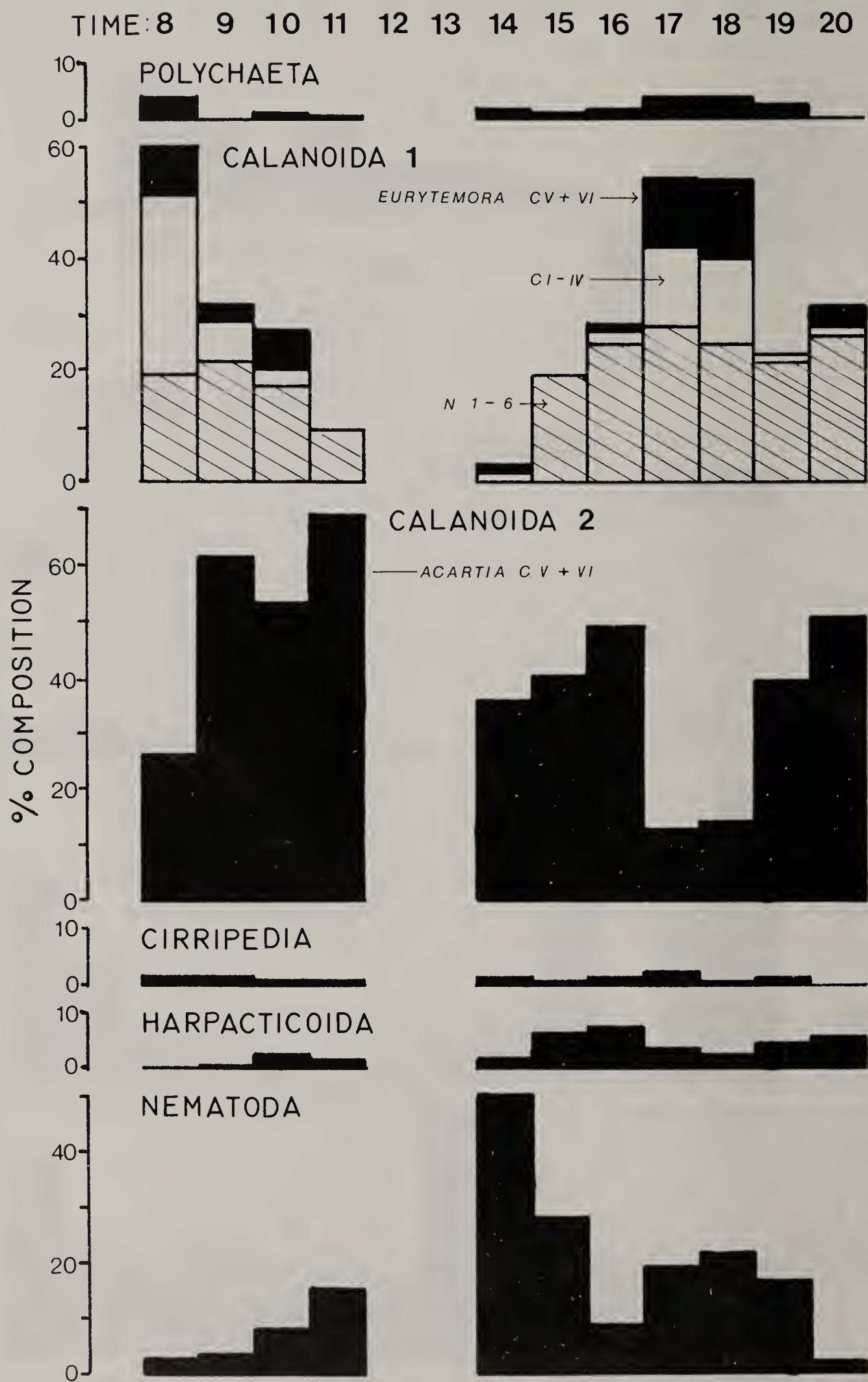


Fig 5. Hourly changes in percent composition of zooplankton at site III (Canard River), 13 July 1978.

Discussion

As indicated above there are considerable difficulties with sampling accurately in rapidly flowing shallow waters, in selecting the optimum mesh and aperture sizes for nets, and restrictions on access to the Basin except at high tide limit the time and extent of sampling. Nonetheless, the major variations appear to be natural ones: marked patchiness in distribution of the major zooplankters and extensive seasonal succession of both holoplanktonic and meroplanktonic components.

Despite the small scale patchiness some generalizations are possible. The spring and early summer plankton of the southern bight is dominated by *E. herdmani*, augmented at times by *Balanus* larvae that are probably allochthonous. In summer, this species is replaced to a large extent in shallower regions by *A. tonsa*, but adult *E. herdmani* are still present in considerable numbers in deeper waters offshore. By October, *A. tonsa* has essentially disappeared from the bight and *E. herdmani* is once again the dominant organism. This pattern of changing dominance is comparable with that described in other estuaries (Jeffries 1955; 1962; Raymont & Carrie 1964; Bousfield et al. 1975).

In species composition also, the zooplankton of the southern bight is similar to that found in the turbid regions of other estuaries, such as Narragansett Bay and Chesapeake Bay. This is in contrast to Jermolajev's (1958) account of the zooplankton of Minas Basin. In 20 to 30 samples collected in Minas Basin in 1920 and 1951 she recorded only 4 species in any number: *A. tonsa*, *E. herdmani*, *Pseudodiaptomus coronatus*, and *Centropages hamatus*. Some of the collections were made with a 570 μm mesh net, and in Minas Basin these apparently retained nothing, since even adult *E. herdmani* and *A. tonsa* pass through such mesh. None of the samples she examined was taken from the southern bight: her nearest station (No. 5 on the *M/V Mallotus*) was somewhat north of our station T near Boot Island. This sample, taken with a 280 μm mesh net on 14 July 1951, included 400 *A. tonsa*, 500 *E. herdmani*, 300 *C. hamatus*, 1 *C. finmarchicus* and 1 *Pseudocalanus minutus*. Similar relative numbers and composition were recorded for stations farther out in Minas Basin, and extremely large numbers of *A. tonsa*, *E. herdmani* and *P. coronatus* were found in samples from Cobequid Bay. Of the species recorded during our studies, only *C. finmarchicus*, *Sagitta elegans* and possibly *Pseudocalanus minutus* are clearly allochthonous.

Much of Jermolajev's discussion revolves around the noted absence of phytoplankton consequent upon great turbulence and high turbidity. In fact many copepods, particularly but not only estuarine ones, have been shown to feed well on non-living particulate material (e.g. Heinle et al. 1976). Our studies also show that most of the common phytoplanktonic species (*Biddulphia regia*, *Coscinodiscus* spp, and *Rhizosolenia* sp) are too large for the resident zooplankters to ingest, and we infer that non-living particulate material is the major source of food for most non-predatory zooplankters in Minas Basin.

It is in recognition of this fact that our studies have been done concomitantly with studies of suspended sediments in the southern bight. As we have shown (Daborn & Pennachetti 1979) the water has rather high levels of suspended sediment (100 - 2,000 mg/l, most of which is fine silt, clay, and sand (5-120 μm), but some of which is saltmarsh detritus. The southern bight has extensive salt marches, and presumably much of the organic production of these is moved around in suspension, to be colonized and decomposed by fungi and bacteria. Studies are presently under way to investigate this link in the food supply of plankton and benthos in southern Minas Basin.

To the extent that abundance may be taken as an indication, production of the

zooplankton is moderately high in the Minas Basin. Preliminary studies by Imrie (1979) and Gilmurray (in litt.) have indicated that *E. herdmani* is an important component of the diet of larval American smelt (*Osmerus mordax*), Black-spotted sticklebacks (*Casterosteus wheatlandi*), and Atlantic silversides (*Menidia menidia*). Thus it appears that the smaller zooplankters play an important role in conversion of non-living particulate matter into fish biomass.

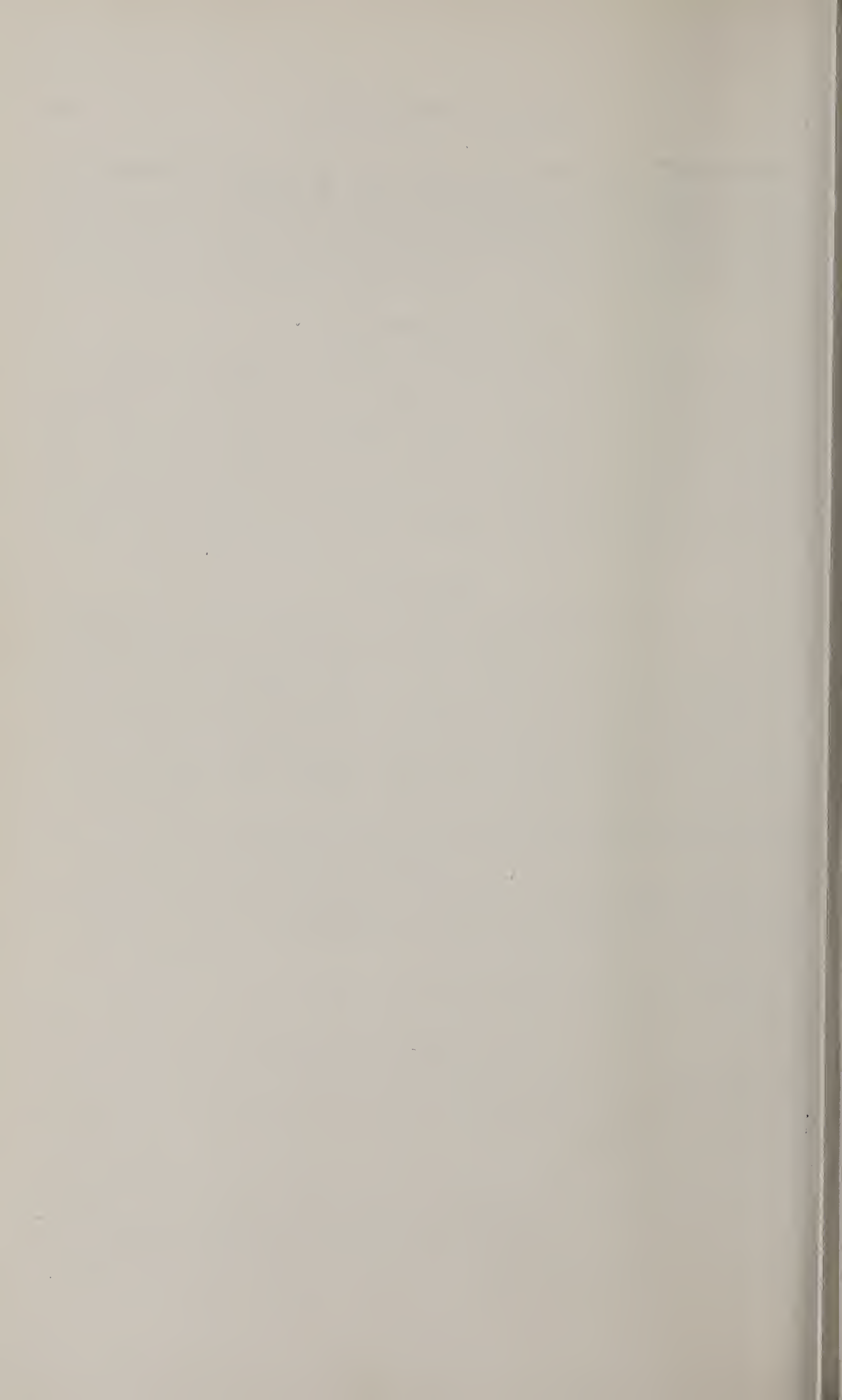
Acknowledgements

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THE DIETS OF FIVE SPECIES OF MIGRANT SHOREBIRDS IN THE BAY OF FUNDY

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Semipalmated Plover *Charadrius semipalmatus*, Black-bellied Plover *Pluvialis squatarola*, Short-billed Dowitcher *Limnodromus griseus*, Semipalmated Sandpiper *Calidris pusilla*, and Least Sandpiper *Calidris minutilla* were collected in the southern bight, Minas Basin, Nova Scotia. The digestive tracts were removed for analysis of gut contents. In 4 of the 5 species studied, most of the prey volume was occupied by the burrowing amphipod *Corophium volutator*. The fifth species, Black-bellied Plover, fed mainly on large polychaetes and nemertean worms.

Introduction

Studies on the feeding ecology of shorebirds have been undertaken primarily on European species over-wintering on coastal estuaries of the British Isles (Goss-Custard 1977) and the Netherlands (Wolff 1969). Similar studies have been conducted on arctic breeding grounds in North America (Holmes & Pitelka 1968) and on South American over-wintering areas (Baker & Baker 1973). Few studies on shorebird feeding ecology have been undertaken at staging areas in North America during migration, except for the work by Recher (1966) in California and Couch (1966) in western Washington.

The mudflats around the head of the Bay of Fundy are probably the most important staging area for migrant shorebirds in eastern North America for 6 to 8 weeks during late summer and autumn (Morrison 1976a; b). During this time, the birds deposit large reserves of energy-rich fat. Semipalmated Sandpipers, *Calidris pusilla* (L.), almost double their weight while in the Bay (unpubl.). This is the final foraging area at which birds can replenish their fat reserves before undertaking a non-stop, transoceanic flight to their South American over-wintering grounds, a distance of some 4,000 km (McNeil & Cadieux 1972). No account of their diet has been published.

Materials and Methods

A total of 102 birds of 5 species—Semipalmated Plover *Charadrius semipalmatus* Bonaparte, Black-bellied Plover *Pluvialis squatarola* (L.), Short-billed Dowitcher *Limnodromus griseus* (Gmelin), Least Sandpiper *Calidris minutilla* (Vieillot), and Semipalmated Sandpiper *Calidris pusilla* (L.), were collected in the southern bight of

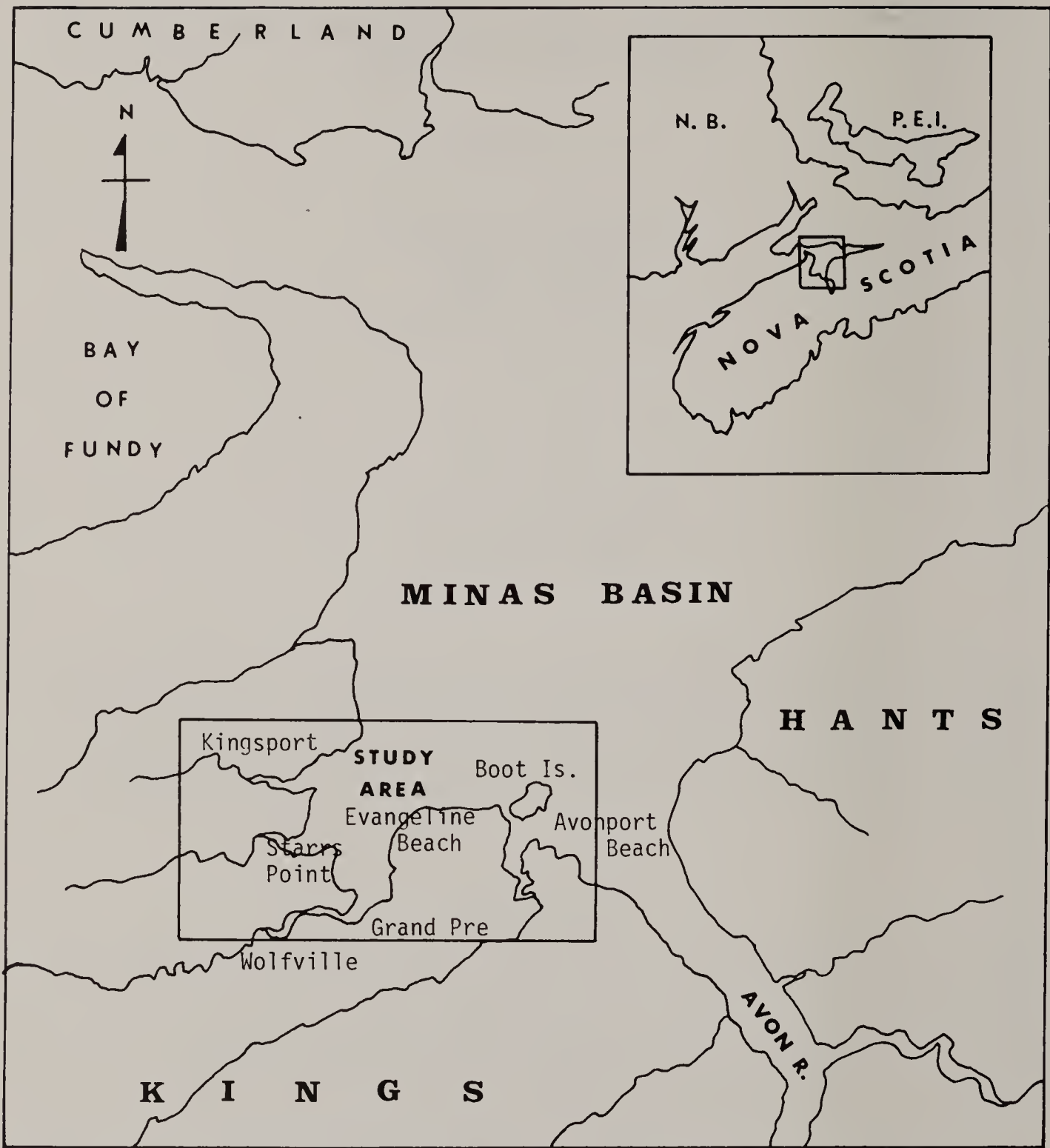


Fig 1. The study area.

the Minas Basin. Collecting sites were Kingsport, Starrs Point, Evangeline Beach, and Avonport Beach (Fig 1). The birds were shot while they actively foraged on the mudflat. The entire digestive tract of each freshly killed bird was removed in the field and placed in a 4 oz. jar containing full strength (40%) formaldehyde. In the laboratory, the contents of the esophagus, gizzard, and intestines were removed and identified as far as possible. Most of the prey were recovered from the gizzard.

The relative proportions of the prey were calculated by displacement in ethanol using a 10 ml graduated cylinder. The results are expressed as percent by volume for each prey species relative to the total prey volume. Polychaete jaws were not included in these calculations as they are known to remain in the gizzards for long periods (Smith 1975), and thus may not have been taken in the study area.

Results

1. Black-bellied Plover

Two Black-bellied Plover were collected on 11 May 1976 and 12 August 1977. Their stomach contents differed greatly, presumably reflecting the different seasons when they were collected. Invertebrate densities in the intertidal sediments are low during May owing to severe ice scouring during the winter months (Yeo 1977). Consequently, in spring, Black-bellied Plover forage mainly in the salt marshes.

Larvae of soldier and horseflies (Order Diptera) comprised 95% by volume of the prey recovered from the gizzard of the spring bird (Table I). Exoskeletal fragments of beetles (Order Coleoptera) accounted for a fraction of the prey. Seventy-eight polychaete jaws (*Nereis* sp) were also found.

The gizzard of the bird collected on 12 August was nearly filled with large body fragments of the polychaete *Nereis diversicolor* Müller (Table I), probably from a single individual, and of the nemertean *Cerebratulus lacteus* (Leidy). Other prey taken were the amphipod *Corophium volutator* (Pallas) and 2 gastropods.

2. Semipalmated Plover

Five adults were collected on 12 July, 12 and 14 August 1977, and 2 immature birds on 9 September 1977. Five of the birds had recently consumed large numbers of *Corophium volutator* (Table II). On the average, *Corophium* made up almost half of the prey volume. Exoskeletal fragments of insects (Diptera and Odonata) were found in 2 adults and the 2 immatures. In the latter, these included undigested wings, suggesting that insects were recently consumed probably at the roost site. Jaws of the polychaetes *Nereis* sp and *Glycera* sp were found in 4 birds and 6 intact specimens of *Heteromastus filiformis* (Clarapède) (Polychaeta) were recovered from 1 digestive tract. Remains of the bivalve *Macoma balthica* (L.) and the gastropods *Hydrobia totteni* and *Turbonilla elegantula* were also present.

3. Least Sandpiper

Nine adult birds were collected on 15, 29 July, and 9 September 1977. The diet (Table III) consisted almost entirely of *Corophium volutator* (88.6%) except for one

Table I. Average percent volume of prey species taken by Black-bellied Plover, 11 May 1976 and 12 August 1977 (listed in order of magnitude).

MAY		AUGUST	
Prey	Percent volume	Prey	Percent volume
Insect larvae (Tabanidae)	54	Polychaeta	65
Insect larvae (Stratiomyiidae)	41	<i>Cerebratulus lacteus</i>	20
Coleoptera	3	<i>Turbonilla elegantula</i>	5
<i>Hydrobia totteni</i>	1	<i>Lunatia heros</i>	4
<i>Dermacentor</i> sp.	1	<i>Corophium volutator</i>	4
		Diptera	2

Table II. Average percent volume and frequency of occurrence (%) of prey species taken by semipalmated Plover (n = 7).

Prey	Percent volume	Frequency of occurrence
<i>Corophium volutator</i>	47.6	71.4
Insects	26.9	57.1
<i>Heteromastus filiformis</i>	12.7	14.3
<i>Macoma balthica</i>	7.1	28.6
<i>Hydrobia totteni</i>	5.6	71.4
<i>Turbonilla elegantula</i>	0.1	14.3

Table III. Average percent volume and frequency of occurrence (%) of prey species taken by Least Sandpiper (n = 9).

Prey	Percent volume	Frequency of occurrence
<i>Corophium volutator</i>	88.6	77.7
<i>Chiridotea caeca</i>	10.2	11.1
<i>Oxyurostylis smithi</i>	0.9	11.1
Insects	0.3	22.2

Table IV. Average percent volume and frequency of occurrence (%) of prey species taken by Short-billed Dowitcher (n = 15).

Prey	Percent volume	Frequency of occurrence
<i>Corophium volutator</i>	70.3	100.0
Polychaeta	24.9	40.0
<i>Buccinum undatum</i>	2.5	6.7
seeds	1.7	6.7
<i>Hydrobia totteni</i>	0.3	6.7
<i>Chiridotea caeca</i>	0.1	6.7
<i>Macoma balthica</i>	0.1	6.7
Insects	0.1	6.7
unidentified	0.2	-

bird that had ingested 71 of the isopod *Chiridotea caeca* (Say) and 5 *Oxyurostylis smithi* Calman (Order Cumacea). Two other birds contained insect fragments.

4. Short-billed Dowitcher

Fifteen adults were collected on 14 and 23 July 1977. *Corophium volutator* were present in all the gizzards examined, and made up the bulk of the prey (Table IV). Six had jaws of polychaetes (*Nereis* sp and *Glycera* sp) and 6 others contained body fragments from those genera, comprising most remaining prey volume. Other minor food items consisted largely of seeds and the gastropod *Buccinum undatum* L.

5. Semipalmated Sandpiper

Sixty-eight birds were collected on 12, 14, 15, 23, 29 July and 1, 12, 14, 17 August, and 9 September 1977. All were adults except 6 birds collected 9 September.

Sixty-six birds fed almost entirely on *Corophium volutator*, which comprised 86.3% of the prey volume recovered (Table V). The shrimp *Crangon septemspinosa* (Say) was an item not found in other species.

Discussion

The amphipod *Corophium volutator* is a main prey for 4 of the 5 shorebird species studied. Black-bellied Plover appeared to feed mainly on large polychaetes and nemertean worms. This impression is based on only 2 specimens, but field observations (unpubl.) also indicate that Black-bellied Plover on the mudflats feed mainly on large polychaetes.

Semipalmated Plover and Short-billed Dowitcher fed mainly on *C. volutator* and, to a lesser degree, also ingested polychaetes. The small calidrine sandpipers fed mostly on *C. volutator*. Immature birds took the largest proportions of insects. This behaviour may be carried over from the breeding grounds, where, a few weeks earlier, they would have fed mainly on insects (Holmes & Pitelka 1968). Goss-Custard (1977), in his study on the feeding ecology of Redshank *Tringa totanus* (L.), suggested that a preference for *Corophium* "may simply reflect a systematic variation in the availability of prey that was associated with prey density." Yeo (1977) found a maximum density of 63,000/m² for *Corophium* in Cobequid Bay. In the

Table V. Average percent volume and frequency of occurrence (%) of prey species taken by Semipalmated Sandpiper (n = 68).

Prey	Percent volume	Frequency of occurrence
<i>Corophium volutator</i>	86.3	97.0
<i>Chiridotea caeca</i>	2.9	4.4
<i>Oxyurostylis smithi</i>	2.1	10.3
Insects	0.9	13.2
Polychaeta	0.8	10.3
<i>Hydrobia totteni</i>	0.1	5.8
<i>Crangon septemspinosa</i>	0.1	1.5
unidentified	6.9	-

southern bight of the Minas Basin, Hicklin (unpubl.) recorded a maximum density of 47,000/m² with a mean density of 20,000/m². Polychaetes are generally found below the mud surface of exposed mudflats whereas *Corophium* emerges from its burrow to feed. Therefore, the high density and availability of *Corophium* in the Bay of Fundy make it an important prey for shorebirds.

In Europe, *Corophium volutator* occurs in saltmarsh ponds and estuarine mudflats in high densities. It is found in a wide range of sediments from almost fresh to near marine conditions (Crawford 1937 in Gratto 1977). The species is not as widespread in North America where it has been reported only in the Bay of Fundy and along the coast of Maine (Shoemaker 1947). Hence, their high densities in the Bay of Fundy appear important in ensuring the rapid weight gain in migrant shorebirds during their short stay in the Bay of Fundy and thus provide the necessary fuel for their successful migration to the over-wintering grounds in South America.

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LENGTH-WEIGHT RELATIONSHIPS, ENERGY CONTENT AND THE EFFECTS OF PREDATION ON *COROPHIUM* *VOLUTATOR* (PALLAS) (CRUSTACEA: AMPHIPODA)

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An intertidal population of *Corophium volutator* (Pallas) was studied at Starrs Point, N.S. where the species occurs in densities up to 52,280/m². Length-dry weight equations for males are different from those for females, and females collected in May show a higher weight to length ratio than those collected in June or July. Energy values averaged 15.07 J mg⁻¹ dry weight for animals $\geq$ 4.5 mm and 17.21 J mg⁻¹ dry weight for those $<$ 4.5 mm. Preliminary experiments to measure the effects of migrant shorebird predation on *C. volutator* show dramatic declines in biomass resulting from the reduction in numbers and mean length of *C. volutator*.

Introduction

The tube dwelling amphipod *Corophium volutator* (Pallas) is widespread and abundant in many of the intertidal mud flats in the upper Bay of Fundy. High densities have been recorded locally for Cobequid Bay (65,000/m²; Yeo 1977), Chignecto Bay (21,300/m²; P.W. Hicklin in verb.) and the Minas Basin (52,280/m²; Boates 1978).

Past studies of this species have concentrated on European populations. Watkin (1941) described the life cycle of *C. volutator* in Wales and Birklund (1977) studied biomass, growth, and production in Denmark. Most relevant to this discussion are the works of Goss-Custard 1977a; b; 1969; (Goss-Custard et al. 1977) in which several aspects of the biology of *C. volutator*, such as density, size frequency distribution, and behavior were considered in relation to the foraging of overwintering redshank *Tringa totanus* (L.). Eighty-seven percent (in terms of numbers) of the diet of this shorebird consisted of *C. volutator* (Goss-Custard 1969).

Only recently has the importance of *C. volutator* as a food resource in the Minas Basin been realized. This amphipod forms a large part of the diet of ground-feeding fishes in the region (Imrie 1979; Yeo 1977). In the summer and autumn, hundreds of thousands of migrant shorebirds, predominantly Semipalmated Sandpipers *Calidris pusilla* (L.), prey heavily upon *C. volutator* prior to further migration to their overwintering grounds in Central and South America and the West Indies.

This paper deals with the relationships of dry weight to length and energy content of *C. volutator*, and also reports on a preliminary 'exclosure' experiment that was devised to measure the effects of vertebrate predation upon this amphipod.

Materials and Methods

Study Area

The study was located at Starrs Point, Kings Co., N.S. (45°08'N, 64°22'W), 6 km north of Wolfville (Fig 1). Here the extreme diurnal tides, characteristic of the region, uncover a long triangular mud flat which at low water extends over 5 km to the northeast. Sediments of the area range from fine sand to clay.

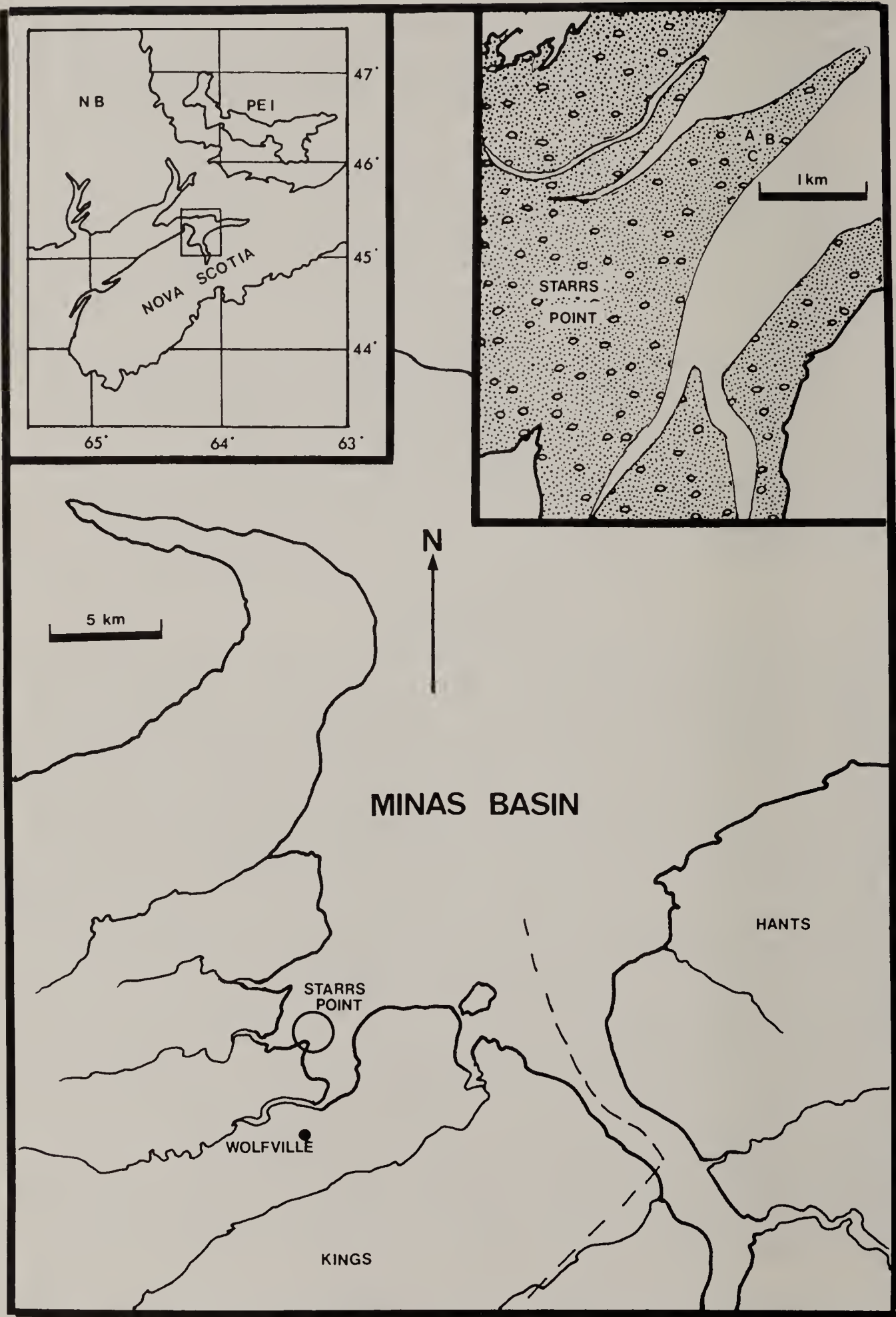


Fig1. Map of the Minas Basin showing the Starrs Point study area and the location of the sample sites. A—site of *Corophium volutator* collections; B—high density enclosure; C—low density enclosure.

Corophium volutator Collections

C. volutator samples were collected for the length-weight studies on 6 May, 8 June, and 15 July 1978 at the location (A) shown in Figure 1. Specimens were removed from the sediment by sieving (Tyler No. 20), placed in jars of seawater, returned to the laboratory and, immediately frozen (-10°C).

Later, the samples were thawed and individuals were sexed, checked for the presence of eggs and/or embryos, and measured to the nearest 0.1 mm (straightened; rostrum to telson) with calipers. Care was taken to ensure that specimens of all lengths present in the sample were included. Specimens were dried to a constant weight (12 h, 70°C) and weighed to the nearest 0.001 mg on a Cahn electrobalance.

C. volutator from the 8 June collection were used for energy determinations. These were sorted into millimeter size classes and dried (24 h, 70°C). Animals in each size class were ground to a homogenous mixture, pressed into pellets, and combusted in a "Phillipson" oxygen microbomb calorimeter.

Ash content was determined by loss of ignition (520°C, 12 h) for each of 13 individuals.

Exclosure Experiments

Two exclosures (each 5 m²), consisting of a metal frame covered with nylon string, were used to exclude predators from 2 areas of mud flat (locations, Fig 1). One exclosure was placed where *C. volutator* were present in high densities and the second in an area where densities were low. The structures were planted on 26 June near the onset of shorebird migration. At this time 6 cores (15 x 15 x 10 cm) were obtained from inside each exclosure and 6 from an adjacent control area 15 m distant. On 6 September, after migration peaked, this procedure was repeated except that 4 cores were collected from each of the 2 control areas. All samples were sieved in the field, preserved, and returned to the laboratory where numbers and lengths of *C. volutator* were determined.

Periodic observation of the exclosures verified that shorebirds feed in their immediate vicinity but rarely inside. The exclosures did not induce any observable changes in the sediment upon which they rested.

Results and Discussion

Length-Weight Relationships

Biomass is often calculated indirectly from its relationship to a more conveniently measured parameter such as length. The need for many biomass determinations for our work on shorebird foraging necessitated the derivation of length-dry weight relationships for juvenile and adult female *C. volutator* in May, June and July. A few measurements were also determined for the less abundant adult male *C. volutator* over the 3 mo of this study.

An exponential relationship described by the equation

$$W = qL^b$$

where q is a constant and the exponent b is the slope or regression coefficient that relates length (L) to weight (W) (Winberg 1971) fits the data best. The results are expressed graphically in Figures 2, 3, and the regression data are found in Table I. In all 4 cases length is highly correlated with dry weight ($r \geq 0.92$). The fact that the regression coefficients for the juvenile-female equations are near 3 suggests that length and weight are added proportionally during growth (Winberg 1971; Daborn

Table I. Length-dry weight regression data for *Corophium volutator*.

	N	q	b	r	length range (mm)
Juvenile-Female					
May	44	0.0054	2.939	0.927	3.5-9.6
June	50	0.0021	3.089	0.978	3.0-9.7
July	99	0.0023	3.164	0.978	2.7-9.0
~	Male				
	22	0.0004	4.3 2 1	0.958	4.3-9.0

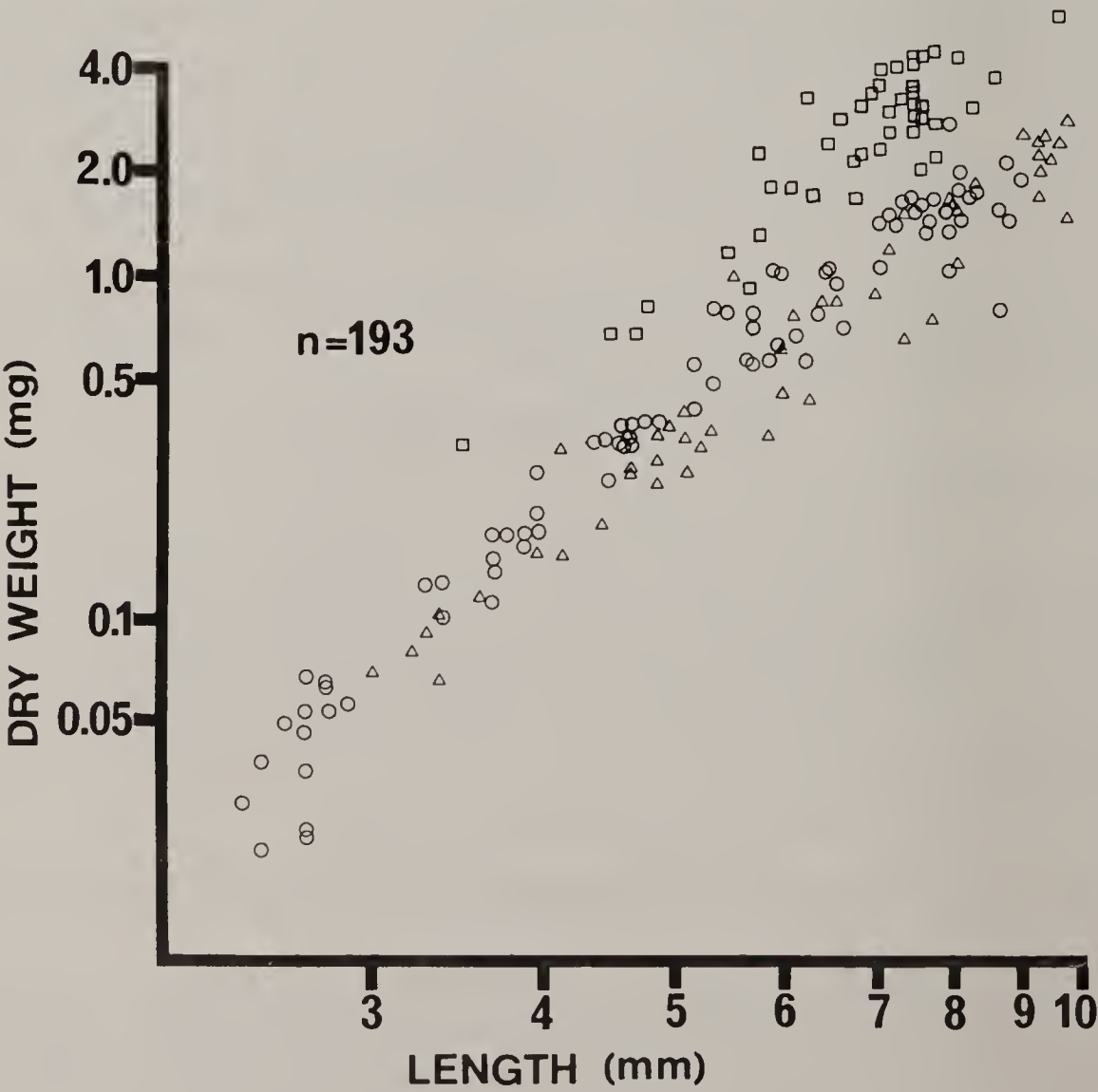


Fig 2. Length-dry weight relationships for juvenile and female *Corophium volutator* in May (□), June (Δ) and July (o).

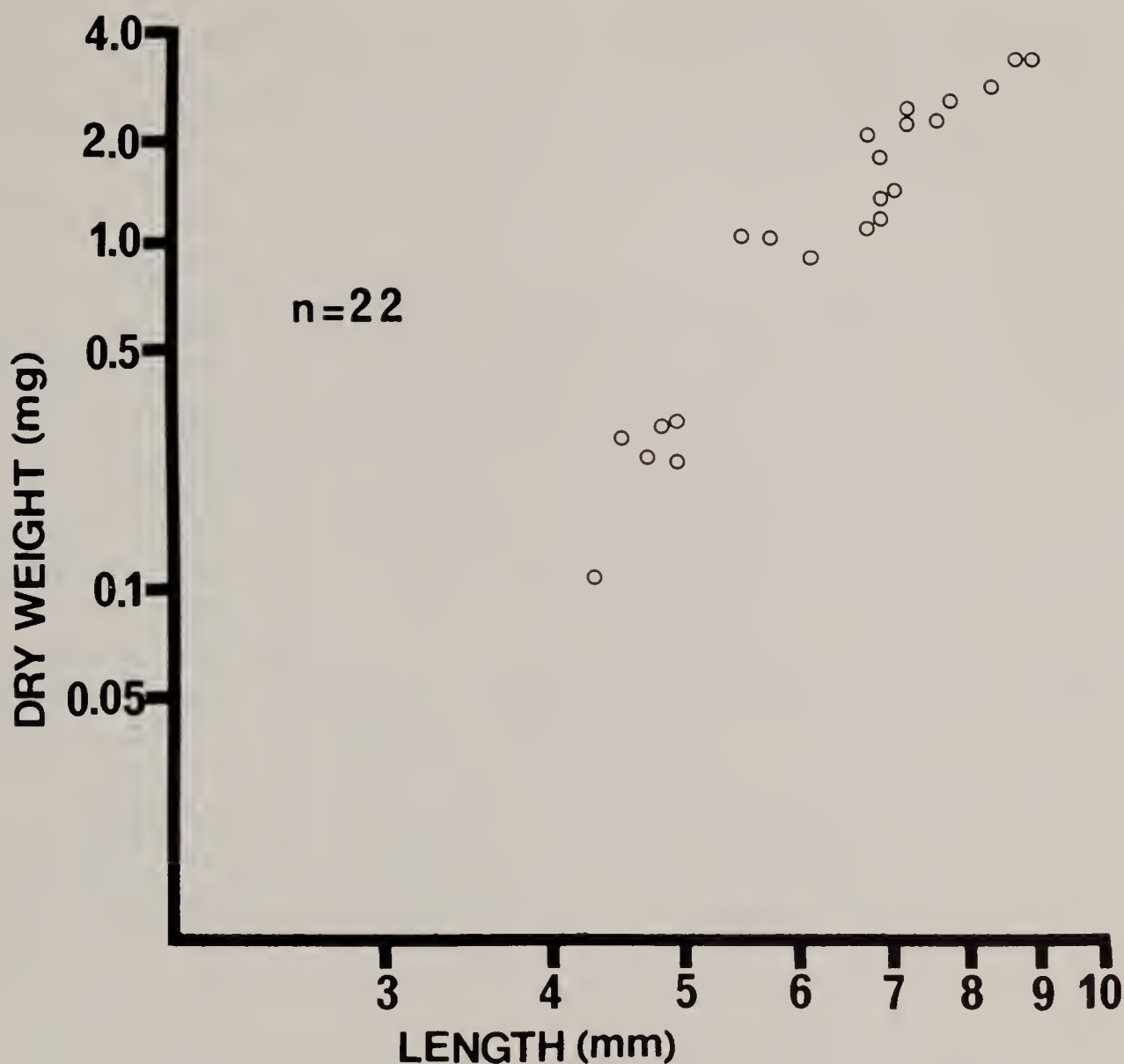


Fig 3. Length-dry weight relationships for male *Corophium volutator*. (May, June, July combined).

1974). This is not true for adult males where a regression coefficient of 4.32 was calculated. This anomaly can be explained by the sexual dimorphism in antennae length characteristic of *C. volutator*. Growth of these appendages in males increases at sexual maturity (~ 4.5 mm) and the ratio of length^3 to weight decreases throughout the growth period. Because our measurements of length (rostrum to telson) do not include antennae, increases in antennae length add to the weight but do not affect length.

An analysis of covariance was used to compare the regressions for juveniles and females combined in May, June and July. The variances of the 3 conditions were not different (Bartlett's test; $X^2 = 0.344$, $p > 0.995$). However, the comparisons of the regression coefficients showed that all 3 values were significantly different (May vs June, $F = 129.5$; May vs July, $F = 360.6$; June vs July, $F = 253.9$). In addition to differing in slope values, the data points for May are displaced above the overlapping values for June and July (Fig. 2). These differences in slope and the displacement of the May data points may be related to the reproductive condition of females. In May 72% of the females were ovigerous whereas in June and July only 17 and 22% respectively of the females carried eggs and embryos. This hypothesis warrants further investigation.

Only 2 accounts of length-weight relationships of *C. volutator* were found in the literature. These were both incidental to the subject of the studies and lack of detail and variability in the methods of data presentation make direct comparison with

our information difficult. The regression coefficients of 2.82 (♂♂) and 2.58 (♀♀) of a Danish population (Birklund 1977) are quite low compared with our values. Yeo (1977), working on Cobequid Bay, reported a regression coefficient for males and females of 1.79 which appears unusually low.

Energy Content

In June, the Starrs Point. *C. volutator* population was comprised of 2 distinct cohorts representing numerically dominant juveniles and a smaller potentially breeding adult component (Fig 4). Uncorrected energy values for each millimeter size class are plotted in Figure 4. A distinct drop in energy value occurred between the 4 and 5 mm size classes. The mean value for all determinations for animals $\geq 4\text{mm}$ is 15.07 Jmg^{-1} dry weight ± 0.08 (SE). A consistent trend in energy value for animals < 4.5 mm length is destroyed by a single determination that yielded the lowest value in this study. Assuming that this value is a mechanical error, the energy value for animals < 4.5 mm in length is 17.21 J mg^{-1} dry weight ± 0.26 (SE).

C. volutator ≥ 4.5 mm in length have a lower energy content than animals < 4.5 mm. The difference does not directly coincide with the division separating the 2 cohorts (~ 6 mm). However, 4.5 mm is the approximate length at which *C. volutator* reaches sexual maturity in Wales (~ 4.0 mm, Watkin 1941). In our study 97% (57 of 59) of the females carrying eggs and/or embryos exceeded 4.5 mm in length.

Variation in the ash content of *C. volutator* does not explain the difference in energy value. The ash content of 13 individuals was variable, ranging from 18.4 to 39.7% (Table II). The mean value, 27.4%, and the variability encountered are not

Table II. Ash content (% by weight) of *Corophium volutator*.

length (mm)	dry weight (mg)	% ash	
7.8	0.720	23.8	
7.4	0.631	18.7	
5.4	0.348	21.6	
8.2	1.499	32.8	
6.4	0.804	26.0	
9.3	1.651	28.1	
6.6	0.806	32.9	
4.7	0.266	18.4	
9.7	2.558	39.7	
3.4	0.099	24.2	
4.5	0.182	18.7	
5.9	0.330	35.8	$\bar{X} = 27.49$
3.6	0.111	36.6	S.D. = 7.402

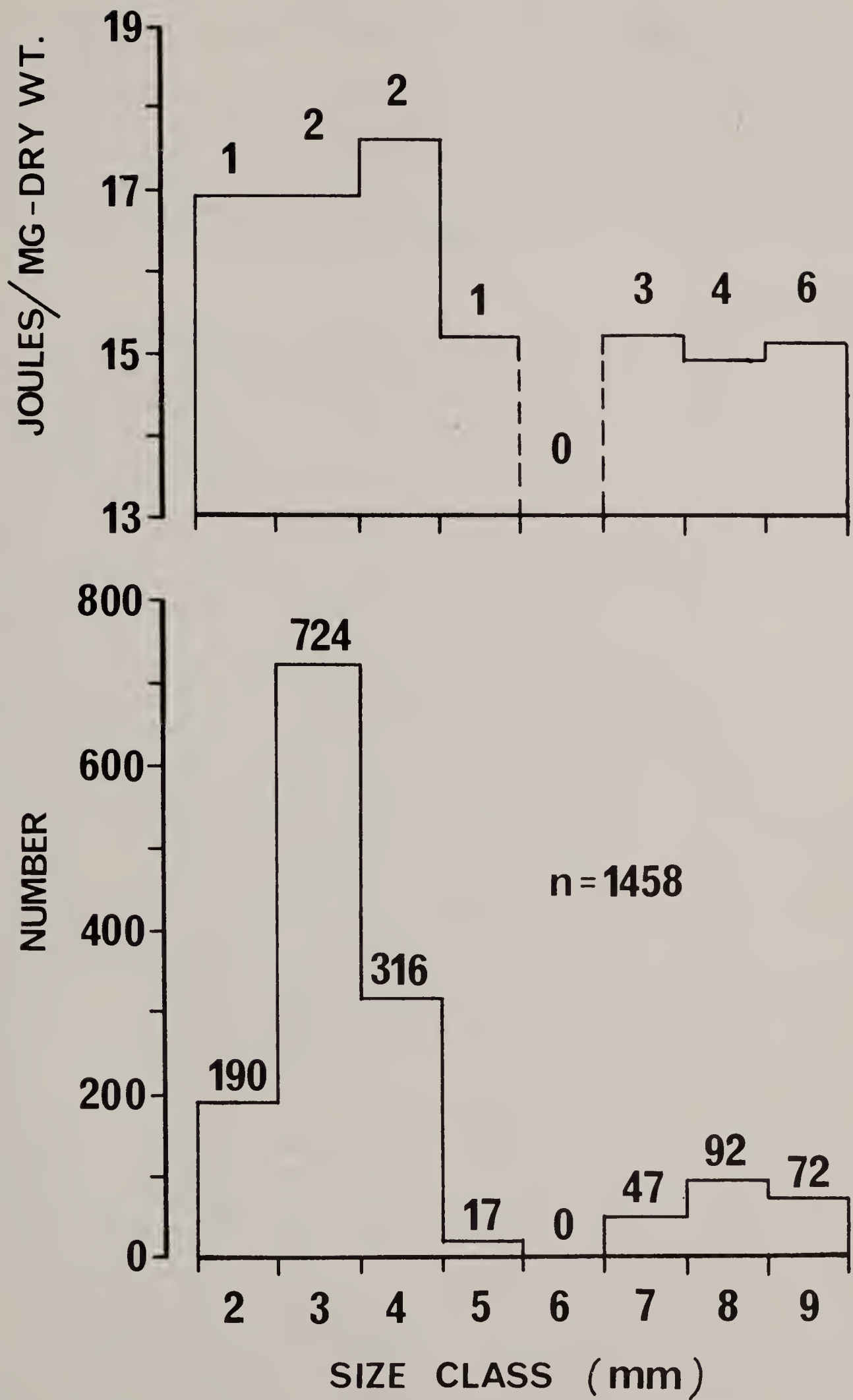


Fig 4.

Energy content and size-frequency distribution of *Corophium volutator* in June.

unusual considering those for other crustaceans (Cummins & Wuycheck 1971; Strong & Daborn 1978).

Information on the energy content of *C. volutator* is limited to a single published record by Wood (in Goss-Custard 1977a). He gives a range of ash-free calorific values for *C. volutator* in the Ythan estuary of 4.17-4.54 at Kcal g⁻¹ dry weight (17.44-19.01 J mg⁻¹ dry wt). When our values are corrected for ash content ($\bar{X}$ ash content 27.5%; Table II) respective values for animals < 4.5 mm and $\geq$ 4.5 mm are 19.21 and 21.25 J mg⁻¹ dry wt. These are somewhat higher than Wood's estimates.

Exclosure Experiments

The location selected for the low density exclosure had much lower numbers of *C. volutator* than adjacent areas. In June, the mean density of *C. volutator* was 429 and 37/m² inside and outside the exclosure respectively (Table III). Inside the exclosure the mean number of animals/sample was the same in June as in September (Mann-Whitney U-test; U = 18.50, p > 0.1). Outside the mean number of animals increased but not significantly (Mann-Whitney U-test; U = 13.9, p > 0.1). The fact that a decrease in numbers was not observed outside the exclosure in September suggests that predation was not greatly affecting the *C. volutator* population in this area or that at such low densities its effects were small and undetectable. The low densities may also explain the absence of a detectable increase in *C. volutator* numbers inside the exclosure.

At high densities, changes in *C. volutator* numbers were more apparent. In June, at the site of the second exclosure (Fig 1), estimates of *C. volutator* abundance were 3707 and 8273/m² inside the exclosure and in the adjacent control areas respectively (Table IV). In September, densities inside the exclosure had increased by a factor of

Table III. Density of *Corophium volutator* inside and outside the exclosure in a low density area.

sample	26 June		06 September	
	inside	outside	inside	outside
1	17	4	4	17
2	20	1	24	1
3	15	0	16	1
4	3	0	6	5
5	2	0	7	
6	1	0	2	
$\bar{X}$ /sample	9.7	0.8	9.8	6.3
S.D.	8.6	1.6	8.5	7.4
$\bar{X}$ /m ²	429	37	437	278

Table IV. Density of *Corophium volutator* inside and outside the exclosure in a high density area.

sample	26 June		06 September	
	inside	outside	inside	outside
1	63	263	803	19
2	125	123	1051	20
3	26	240	1038	191
4	94	135	1214	30
5	57	161	841	
6	136	196	1035	
$\bar{X}$ /sample	83.5	186.3	977.0	65.0
S.D.	42.5	56.8	61.9	84.2
$\bar{X}/m^2$	3707	8273	44267	2886

11.9 whereas the density in the control area decreased by a factor of 2.9. The increase (83.5 to 997.0/sample) represents the growth rate of the population and natural mortality as predation is not a limiting factor here. The decrease in the control area is attributed to predation, largely by shorebirds. Groundfish predation in the immediate area of the experiment was probably low as we did not find any of the feeding pits or traces that are characteristic of the fishes feeding on Minas Basin mud flats (Risk & Craig 1976). If *C. volutator* in the control area had reproduced in the absence of predators, expected densities in September would be 1,527, 627/m², assuming no density dependent limitations on population growth or limitations similar to those inside the exclosure.

Figure 5 shows the size frequency distribution of *C. volutator* inside and outside both exclosures in September. In both the high and low density situations, specimens from inside were on average longer ($\bar{X}$ = 3.50 and 3.15 respectively) than those from the control areas ($\bar{X}$ = 3.16 and 2.59 respectively). Statistical analysis showed that the difference between the distributions inside and outside is not chance (high density: $t = 5.40$, $p < 0.001$ and low density: $t = 1.70$, $0.1 > p < 0.05$). In the high density area the differences in length alone represent 27% more biomass inside the exclosure than outside. If the differences are attributed to predation, shorebirds may be selecting for larger individuals. Goss-Custard (1969) found that overwintering redshank similarly selected larger *C. volutator* and P.W. Hicklin (in verb.) observed that migrant Semipalmated Sandpipers in the Bay of Fundy take large *C. volutator*. Analysis of stomachs of shorebirds collected from near the exclosure sites will clarify this observation.

A similar study (Schneider 1978) showed that shorebirds in Massachusetts feed in a manner that equalizes the relative abundance of prey species but he did not investigate size related effects. In our area Semipalmated Sandpipers feed almost en-

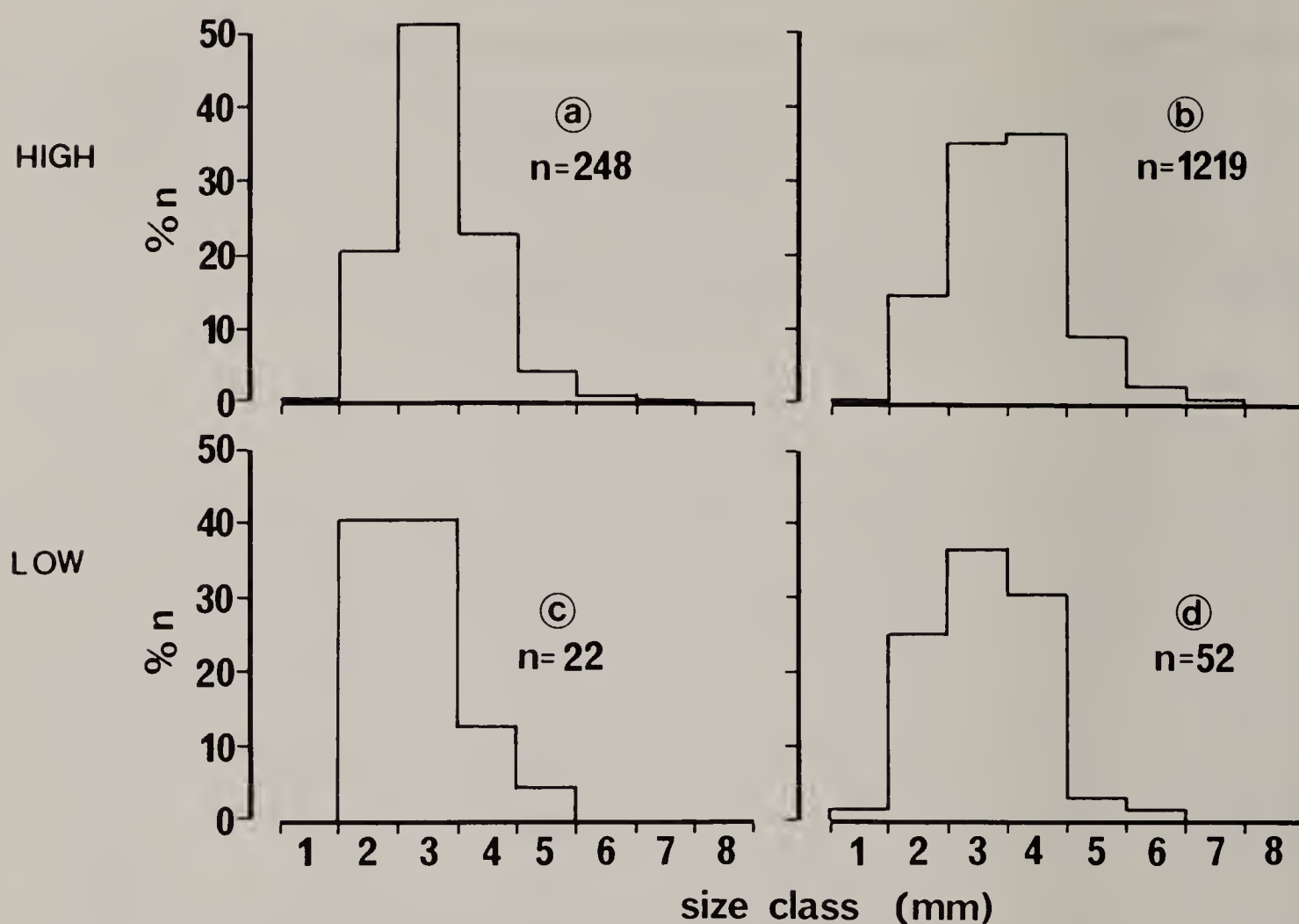


Fig 5. High (upper) and low density (lower) size-frequency distribution of *Corophium volutator* collected inside the enclosure (b and d) and outside (a and c).

tirely on *C. volutator*, and it seems that other prey species serve to supplement the diet when *C. volutator* are unavailable.

Schneider (1978) also found that numbers of invertebrates inside the exclosures did not change whereas numbers outside declined. This suggests that, unlike *C. volutator* in our study, reproduction did not occur over the duration of his work.

Our work, thus far, suggests that migrant shorebirds greatly decrease biomass of *C. volutator* by reducing numbers and possibly by selecting for larger individuals.

Acknowledgements

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LIPIDS AND FATTY ACIDS OF *COROPHIUM VOLUTATOR* FROM MINAS BASIN*

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Corophium volutator from Minas Basin, Bay of Fundy, had about 1.2% lipid made up of 55.3% phospholipid, 31.4% triglyceride, and minor amounts of other lipids. This lipid composition is similar to that found in other estuarine and shoreline crustaceans not utilizing storage lipids during part of their annual cycle. The fatty acids of the phospholipids and triglycerides were those characteristic of marine lipids. Some interrelationships among monoethylenic fatty acids and among longer-chain polyunsaturated fatty acids of these 2 lipid classes are discussed. The more interesting aspects of these fatty acids were, however, found in a minor lipid class, thought to be sterol ester, for which comparative data are lacking.

Introduction

The burrowing amphipod *Corophium volutator* (Pallas), a common intertidal animal in Europe, is apparently limited in distribution in North America to the Bay of Fundy and the coast of Maine (Gratto 1978). In Minas Basin this animal is one of the most abundant invertebrate species, and it is the dominant inhabitant of fine sediments (Gratto 1978). Densities exceeding 20,000 individuals per m² are not uncommon (Boates 1978), and 73,000 per m² have been reported (Gratto 1978). This species is present the year round with maximum numbers in early summer following reproduction.

C. volutator is reported to be the most important food for shore birds in the area, and also forms part of the diet for groundfeeding fish. The mean calorific value of May samples, corrected for ash, was 5.01 cal per mg (Boates 1978). The lipid content of *C. volutator* is of the order of 1 to 1.5% (wet weight), and only about one-third is triglyceride. The energy contribution to shore birds must, therefore, rest on quantity of *C. volutator* available rather than on a high content of lipid.

Because of the obvious importance of *C. volutator* in the food web of Minas Basin, we undertook an examination of the lipids and fatty acids of this species, and the results are reported herein.

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Materials and Methods

C. volutator were collected in early December 1978, and again in early February 1979, near Starr's Point, Minas Basin. Three analyses (lots I-III) were conducted on the December sample and one analysis (lot IV) on the February sample. Lot I (8 individuals, 0.13 g) was placed in a centrifuge tube (10 ml, Teflon-lined screw cap) with distilled water (0.3 ml), MeOH (1.0 ml), and 50% NaOH (0.2 ml). The tube was flushed with nitrogen, capped, and heated for 1 h at 100°. After cooling, water (1.5 ml) was added, and the aqueous alcohol phase was extracted twice in situ with petroleum ether (1.5 ml per time). The petroleum ether extract was examined for sterols. The aqueous phase was acidified with 12N HCl and the fatty acids were recovered into petroleum ether (2 extractions as described above) and transferred to a screw-capped tube. The petroleum ether was removed with a jet of nitrogen and MeOH (1 ml) and 14% BF₃-MeOH (1 ml) were added. The tube was flushed with nitrogen, heated for 1 h at 100°, and cooled. Water (2 ml) was added and the methyl esters recovered by 2 extractions with petroleum ether (1.5 ml per time). The combined petroleum ether solutions were washed once with H₂O (1 ml) and concentrated for GLC (gas-liquid chromatography) analysis of the methyl esters (Ackman 1972). About half the methyl ester sample was dissolved in EtOH and hydrogenated over Pt catalyst (Ackman & Burgher 1964) for quantitative (Ackman et al. 1967) and qualitative examination of minor branched chain fatty acids (Ackman & Sipos 1965; Ackman et al. 1967).

Lot II of *C. volutator* (0.61 g) was extracted in a screw-capped centrifuge tube with CHCl₃ (2 ml) and MeOH (1 ml), with intermittent agitation over a period of 3 h. Water (2 ml) was added, the separated CHCl₃ layer transferred to another tube, and the residual material re-extracted with additional CHCl₃ (1 ml) and MeOH (0.5 ml) for one-half hour. The CHCl₃ extracts were combined and centrifuged. The clear chloroform solution was removed and freed of solvent, first by nitrogen jet and then by exposure to high vacuum. The lipid recovered (1.3%) was used for lipid class analyses (Table I) by Iatroscan (see below).

A third lot (frozen en bloc, 2.8 g) was blended for 1 min in a Sorvall Omni-Mixer (50 ml cup) with CHCl₃ (20 ml) and MeOH (30 ml). The blend was filtered, the filter washed with CHCl₃ (10 ml), water (20 ml) was added to the filtrate, and after agitation the CHCl₃ layer was separated and evaporated to yield lipid at 0.7% of the weight of sample. This lipid was dissolved in CHCl₃ and streaked on a TLC (thin-layer chromatography) plate (Adsorbosil-5 Prekote, Applied Science Laboratories, pre-developed with ethyl acetate) and developed in petroleum ether:diethyl ether:acetic acid (85:15:1). Lipids (5 bands) were detected by spraying with 2, 7-dichlorofluorescein and viewing under UV light. The band at the origin was considered to be phospholipid with small amounts of pigments, etc. Above this was a definite band located opposite a standard cholesterol spot. A diffuse free fatty acid band was also identified by a standard. Above the strong triglyceride band (R_f 0.6) was an obvious but broad band (R_f 0.8), initially thought to be either or both of wax esters or sterol ester. Lipid bands were recovered from the silica gel with CHCl₃ (3 ml) followed with 3 ml of CHCl₃:MeOH (1:1). The pooled solvents were centrifuged lightly and transferred to a clean tube before evaporation. The fatty acids of the phospholipids and triglycerides were converted to methyl esters by heating with BF₃-MeOH (see above). The band of greatest R_f was saponified (see above) and the unsaponifiables were recovered separately from the fatty acids. The latter were converted to methyl esters (see below).

For lipid class analyses, Chromarods (Iatron Laboratories Inc., Tokyo, Japan) were spotted and developed for 20 min in petroleum ether:benzene:formic acid (80:20:1),

Table I. Lipid classes of *Corophium volutator* (w/w%) as determined by Iatroscan analysis of lot II material

	w/w%	Chromarod R _f
Phospholipid	55.3	0.00
Sterol	3.0	0.16
Triglyceride	31.4	0.35
Glyceryl ether?	4.9	0.48
Free fatty acid	5.0	0.58
Sterol ester, hydrocarbon*	0.4	0.92

*Combined in band of R_f 0.8 on TLC plate in proportions of 1:4.

dried briefly, and then redeveloped in petroleum ether:diethyl ether:formic acid (96:4:1) for 20 min before drying and analysis by Iatroscan (Sipos & Ackman 1978). The results are given in Table 1.

The total unsaponifiable material of lot I was examined for sterols by a gas-liquid chromatographic procedure (Kovacs et al. 1979). The unsaponifiable material from the most mobile band on TLC of lot III (see above) was recovered and examined by GLC, initially under conditions suitable for C₁₆-C₂₀ hydrocarbons and later under conditions similar to those for sterols.

The respective methyl esters of fatty acids from triglycerides and phospholipids, after hydrogenation for quantitation studies, were also subjected to urea complex treatment (Ackman & Hooper 1968) to confirm the methyl-branched and isoprenoid structures.

Live animals of Lot IV (0.486 g), freed of water on filter paper, were extracted with CHCl₃-MeOH as described above for lot III. The lipid recovery was 1.72%. The broad top lipid band from a TLC plate was recovered for Iatroscan Chromarod examination and the triglyceride band was recovered, the lipid saponified, and the nonsaponifiable matter removed. The fatty acids were recovered and converted to methyl esters by heating for 1 h with 7% BCl₃ in MeOH (Brian et al. 1972). The analyses of these esters, hydrogenation, and urea complex treatment followed the procedures outlined above.

Results and Discussion

Lipids

The inclusion of water and inorganic particles evidently resulted in low lipid recovery from lot III, but lot IV (recovery 1.7%) and lot II (recovery 1.3%) may be taken as reasonable values for *C. volutator* collected in winter. The proportions of non-polar (phospholipid) material in the lipids of these animals was thus 0.7-0.9% (Table I). Note that in Figure 1 the phospholipid signal is attenuated by a factor of 10.

The lipids of many small pelagic crustacea have been investigated (Sargent et al. 1977; Lee & Hirota 1973) with particular reference to storage (depot) fats in the form of wax esters and triglycerides. Relatively little is known about isopods, etc. which

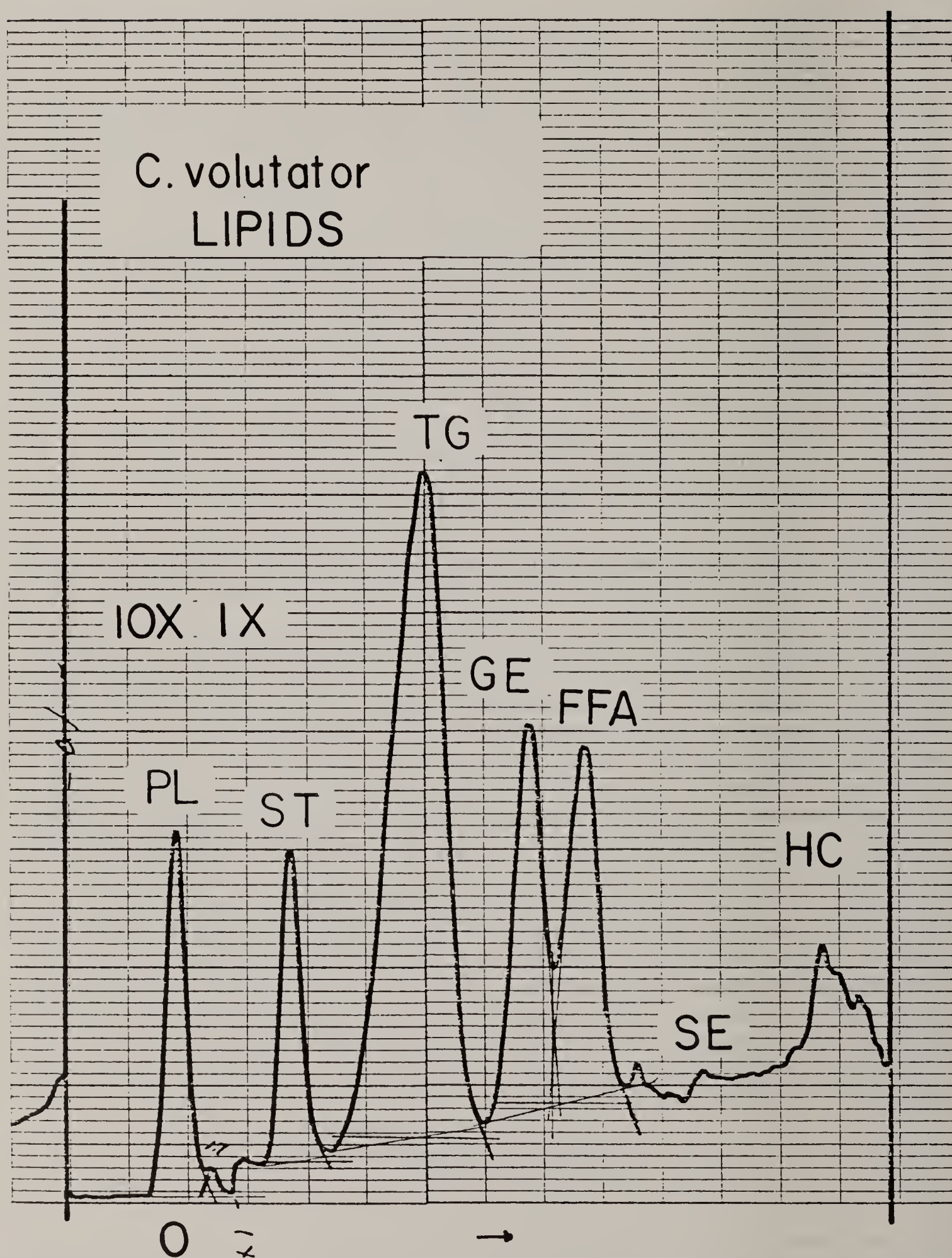


Fig 1. Recording of Chromarod separation of *C. volutator* lot III total lipids. Double development with first solvent of petroleum ether:benzene:formic acid in volume proportions 80:20:1 and second solvent of petroleum ether:diethyl ether:formic acid in volume proportions at 96:4:1. Note attenuations (X). Abbreviations are: PL = phospholipids, ST = sterols, TG = triglycerides, GE = glyceryl ethers, FFA = free fatty acids, HC = hydrocarbons, SE = sterol esters, O = origin. Arrow shows direction at development.

are found along the shoreline (e.g., Gopalakrishnan et al. 1977; Strong & Daborn 1978), but it seems probable that they are biochemically active for most of the year and therefore that lipid turnover (Morris et al. 1973; O'Rourke & Monroe 1976) would occur in winter. In Nova Scotia, the mud-dwelling amphipod *Pontoporeia femorata* had a total of 3.0% (wet weight basis) lipid, including 71.6% triglycerides and 15.9% polar (phospho-) lipid. However, this was an unusual case of lipid development (Paradis & Ackman 1976a; 1976b). In the same study the mysid, *Mysis stenolepsis*, was found to have 1.5% lipid with 38.9% as triglyceride and 37.2% as polar lipid.

Total lipid is quite variable in whole crustacea because of the importance of storage lipids (i.e., wax ester referred to above) in some pelagic species (Takahashi & Yamada 1976). Thus if the total lipid exceeds 1 to 2%, the proportion of phospholipid in total lipid will be depressed. The significance of this is that phospholipid is a functional lipid characteristic of membranes in muscle cells, gills, etc. (Sargent 1976; Chapelle 1978), and tends to be a reasonably high and constant proportion (0.5-1.5%) of the whole animal when muscle, gill, and other organs are a high proportion of sample (Zama et al. 1976; Martin & Ceccaldi 1977). A low level (1-2% wet weight) of total lipid seems to be typical of crustaceans with a fairly invariant habitat and thus not exposed to varying food intake and a need to accumulate substantial levels of depot fat to offset periods of poor food availability (Shul'men & Shchepkin 1974; Lawrence 1976). Under unusually favorable circumstances, high percentages of lipids (21-33% of dry weight) were reported for *Crangon crangon*, *Gammarus salinus*, *Neomysis integer*, *Praunus flexuosus*, and *Orchestia gammarella*, although further work showed that half these percentages might be more normal (Moore 1976). Phospholipid was relatively constant for each species, amounting to 24 to 33% of the lipid. The total percentage of lipid and polar-lipid class proportions of *C. volutator* (Table I) is thus not exceptional for estuarine crustaceans. The total sterols recovered from lot I animals were identified and measured as cholesterol, 85%; 22-dehydrocholesterol, 8%; 24-methylenecholesterol, 3%; and desmosterol, 4%. Cholesterol is usually the dominant sterol in crustaceans, but they lack the ability to biosynthesize cholesterol (O'Rourke & Monroe 1976) and other sterols may be stored as precursors or as substitutes.

The total lipid upper band (R_f 0.8 on TLC plates) had been presumed initially to be all sterol ester until a low recovery of fatty acids from this band in the lot II analysis was noted. This suggested the need for additional work (see lot IV treatment). On re-examination no obvious fatty alcohol component was noted and the fatty acids (Table II) do not provide evidence for any special type of lipid, although generally exogenous fatty acids are strongly represented. The GLC analysis of the intact lipid of R_f 0.8 conducted at high temperature showed a homologous series of unidentified compounds eluting somewhat ahead of cholesterol on the liquid phase OV-17. These were later tentatively identified as hydrocarbons by latroscan (Fig 2). This band is thought to be a mixture of sterol esters and longer chain hydrocarbons in relative proportions of 1:4. No other lipid class could be identified, but no special search was made for some possible components such as wax esters based on phytol (Withers & Nevenzel 1977). The presumed homologous series of hydrocarbons could be derived locally from plants (Nishimoto 1974), or even be included in the cuticle lipids of the *C. volutator* itself (cf. Hamilton et al. 1975; 1976; Lee 1975). The occurrence of hydrocarbons up to C_{30} , and of ketones to C_{24} , in pelagic crustaceae such as *Acanthomysis* sp has been thoroughly investigated (Yamada 1972). The origin of hydrocarbons in biological samples is extensively discussed in the literature. However, at the moment it is not possible to exclude the occurrence of these hydrocarbons as artifacts or contaminants (Whittle et al. 1974; Mironov & Shchekaturina 1976; Zsolnay 1977).

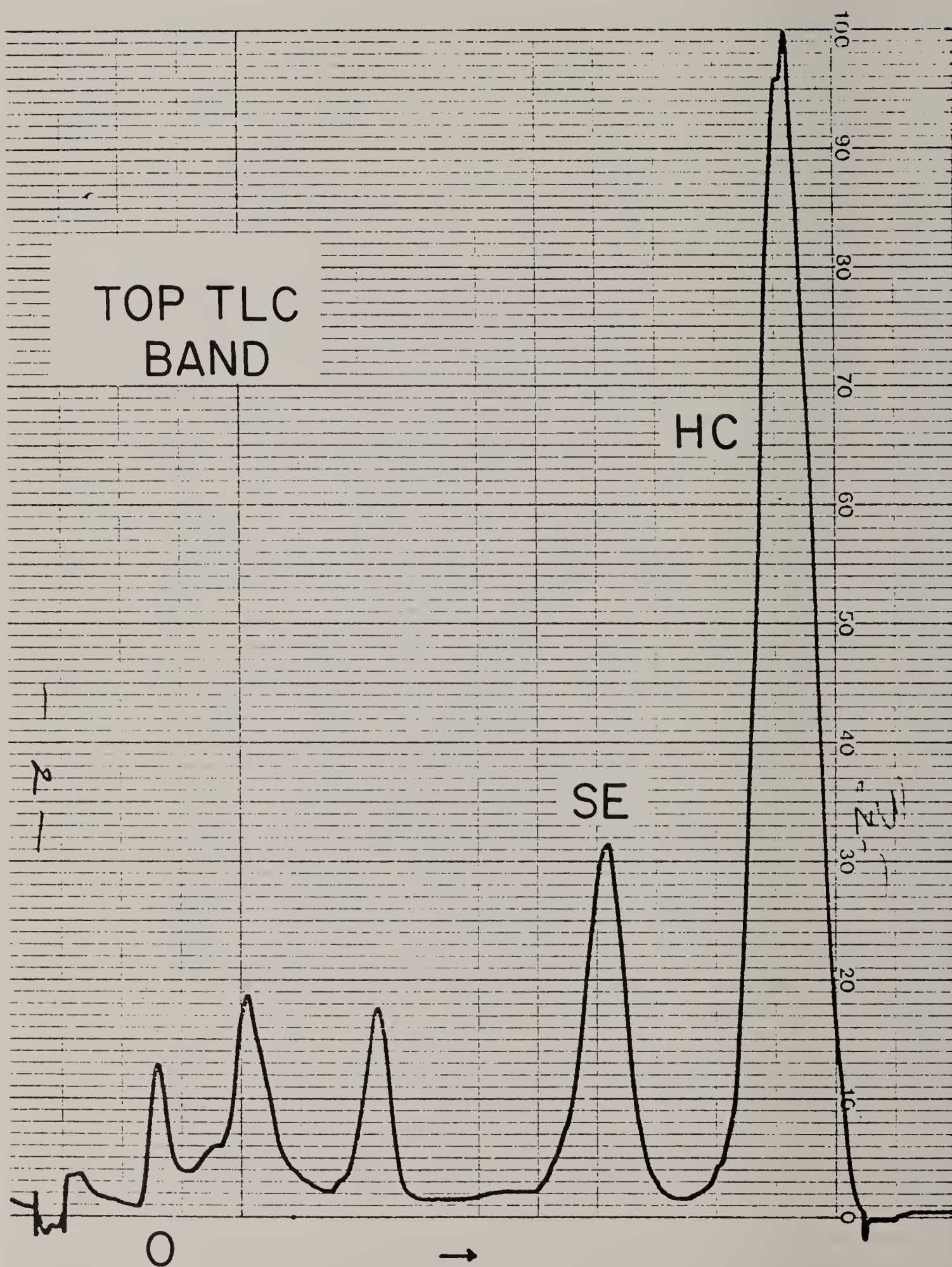


Fig 2. Recording of Chromarod separation of upper band recovered from TLC plate (see text) separation of *C. volutator* lot IV total lipids. Double development with first solvent of petroleum ether:benzene:formic acid in volume proportions of 86:14:1 and second solvent of petroleum ether:diethyl ether:formic acid in volume proportions of 97:3:1. Abbreviations are: SE = sterol esters, HC = hydrocarbons.

Fatty Acids

The proportions of some of the important saturated fatty acids in the TG (triglycerides) and PL (phospholipid) fractions show minor differences; the former has more 14:0 (and 12:0), the latter more 18:0 and also more 20:0, 22:0, and 24:0. In the respective lipids of the zooplankton *Meganyctiphanes norvegica* and *Thysanoessa inermis*, there was also much more 14:0 in the TG than in the PL (Ackman et al. 1970), but in other estuarine crustaceans there seemed to be little difference in 14:0 content of these lipid fractions (Morris et al. 1973; Moore 1976). The longer chain saturated acids, 20:0, 22:0, and 24:0, are seldom important in crustaceans (Morris 1973) except in surface lipids (Hamilton et al. 1976). The iso, anteiso, and straight-chain, odd-carbon fatty acids are also not commonly reported in the literature, but are present in proportions similar to those recorded for the above mentioned zooplankters. Except under special circumstances (Paradis & Ackman 1976a), the C_{15} and C_{17} acids, including branched chain acids, total about 1% each in lipids of almost all marine organisms (Ackman & Sipos 1965), the exceptions being the photoplankters (Ackman et al. 1968) and the seaweeds (Ackman & McLachlan 1977). There is every reason to assume that such fatty acids are normally biosynthesized in marine animals, but they also could possibly be contributed by endogenous bacterial lipids, and also by those living on detritus etc. (Cranwell 1976). It seems likely that the more obvious presence of the isoprenoid acids in the phospholipids is related to structural similarities enabling these acids to mimic the longer chain saturated acids, especially 16:0 (palmitic acid). The upper-band fatty acids, probably from sterol esters, are relatively deficient in saturated fatty acids, but percentages of iso and anteiso odd-chain (C_{15} , C_{17}) acids seem to be higher than in the other lipid groups. Among the unknowns of Table II were a few minor components visible in both the raw and hydrogenated esters. In the phospholipid sample these clearly included aldehyde and/or acetal breakdown products (Ackman 1972) emerging very slightly after iso 14:0 and iso 16:0, indicating the original presence of plasmalogen lipids. Certain other minor components were the subject of further study (see below).

Two aspects of marine monoethylenic fatty acids are of special interest. In general a high proportion of 18:1 ω 7 to 18:1 ω 9 reflects de novo biosynthesis of 16:0 and of the associated 16:1 ω 7 which is then chain-extended to 18:1 ω 7. In the TG of lot III *C. volutator*, this is evidently taking place since 18:1 ω 7 at 3.35% exceeds 18:1 ω 9 at 2.98%. The TG of lot IV (Fig 3) confirm that 18:1 ω 7 is very important to *C. volutator*, and it can be concluded that the diet does not include a high proportion of preformed fatty acids, and that dietary carbon compounds are broken down and resynthesized into monoethylenic fatty acids as required. The second interesting aspect of monoethylenic fatty acid biochemistry is based on the recent conclusion that 20:1 and 22:1 fatty acids have no obligatory role in aquatic lipids except in the form of the corresponding fatty alcohols of copepod wax esters (Ackman et al. 1979; Ratnayake & Ackman 1979a; 1979b). Since exogenous 22:1 ω 11 of copepod origin is not freely available to *C. volutator*, only traces of the chain shortening products 18:1 ω 11 and 20:1 ω 11 are observed (Table II). In the lot IV TG (details not tabulated) 22:1 ω 11 was two-thirds of 22:1 ω 9 and accordingly 20:1 ω 11 was a higher proportion of the 20:1 isomers than in the TG of lot III.

An unusual component fatty acid from the upper band was tentatively identified from GLC retention data as a monounsaturated iso acid, since it disappeared on hydrogenation at the same time as iso 15:0 increased in proportion. A similar acid was noted in a Nova Scotian seaweed (Ackman unpubl.), and probably these acids may be more common than hitherto suspected (Fukushima et al. 1978). Iso acids in

Table II. Fatty acids (w/w%) recovered from whole *Corophium volutator* (lot I) and from individual lipid classes (lot III)

Fatty acids	Saponification	Extracted lipids		
	Total fatty acids	Triglyceride fatty acids	Phospholipid fatty acids	Upper band fatty acids
Saturated acids				
12:0	0.02	0.19	0.01	0.05
Iso 14:0	0.21	0.03	ND	0.03
14:0	2.38	3.12	1.01	2.28
Iso 15:0	0.18	0.28	0.05	0.32
Anteiso 15:0	0.07	0.17	0.02	0.23
15:0	0.54	0.61	0.25	0.65
Iso 16:0	0.08	0.11	0.06	0.13
16:0	18.25	16.24	18.40	9.07
Iso 17:0	0.51	0.39	0.65	1.17
Anteiso 17:0	0.14	0.10	0.28	0.82
17:0	0.76	0.43	0.72	0.28
Iso 18:0	0.05	0.02	0.09	0.03
18:0	1.73	0.67	2.14	1.25
19:0	0.05	0.03	0.10	0.03
20:0	0.08	0.07	0.26	ND
22:0	0.07	ND	0.42	ND
24:0	0.14	0.02	0.17	ND
4,8,12-TMTD	0.07	0.04	0.14	0.01
2,6,10,14-TDPD	0.14	0.02	ND	ND
3,7,11,15-TMHD	0.44	0.08	0.68	0.83
7-M-16:0	0.08	0.05	0.08	ND
Unknowns, total	1.56	0.51	5.21	2.22
TOTAL	27.1	23.2	29.5	17.4

Monoethylenic acids

14:1ω9	0.03	0.02	0.01	0.51
14:1ω7	0.12	0.02	0.02	0.13
14:1ω5	0.06	0.10	0.01	0.11
16:1ω11	0.05	0.03	0.01	0.08
16:1ω9	0.08	0.20	0.01	4.95
16:1ω7	5.05	15.01	3.33	10.45
16:1ω5	0.06	0.16	0.03	0.10
17:1ω8	0.16	0.05	0.12	0.08
18:1ω13	0.05	0.05	0.01	0.07
18:1ω11	0.03	0.04	0.01	0.32
18:1ω9	8.54	2.98	9.18	10.94
18:1ω7	5.84	3.35	5.72	5.43
18:1ω5	0.10	0.08	0.10	0.28
19:1	0.26	0.27	0.29	0.31

20:1ω11	0.03	0.03	0.05	0.04
20:1ω9	1.36	0.32	2.02	0.84
20:1ω7	1.09	0.32	1.02	0.46
22:1ω11	ND	ND	0.04	ND
22:1ω9	0.08	0.03	0.38	0.08
22:1ω7	0.05	ND	0.32	ND
24:1ω9	0.02	0.01	0.14	ND
trans 16:1ω13?	0.05	ND	0.03	ND
16:1ω3?	0.11	0.03	0.01	ND
Iso 15:1?	0.02	ND	ND	0.25
TOTAL	27.1	23.1	23.9	36.2

Polyethylenic acids

16:2ω6	0.49	0.80	0.02	0.18
16:2ω4	1.11	1.46	0.08	2.51
18:2ω7	0.05	0.02	0.02	0.06
18:2ω6	1.10	0.75	0.96	2.17
18:2ω4	0.50	0.55	0.31	0.43
20:2ω6	0.74	0.21	0.47	0.39
16:3ω4	2.91	3.98	0.34	2.82
18:3ω6	0.28	0.59	0.10	0.47
18:3ω4	0.03	0.03	0.01	0.08
18:3ω3	0.28	0.53	0.12	0.47
20:3ω6	0.07	0.06	0.19	0.30
20:3ω3	0.05	0.05	0.12	0.13
16:4ω3?	0.01	0.02	0.01	0.06
16:4ω1	1.65	1.70	0.25	0.93
18:4ω3	2.62	4.28	0.51	2.57
18:4ω1	0.04	0.08	0.02	0.17
20:4ω6	3.01	0.95	4.72	3.47
20:4ω3	0.14	0.27	0.10	0.36
22:4ω6	0.05	ND	0.12	ND
20:5ω3	25.83	30.61	21.32	27.45
21:5ω3	0.93	1.29	0.83	0.51
22:5ω6	0.56	0.19	1.70	0.19
22:5ω3	0.38	0.20	0.55	0.20
22:6ω3	7.05	5.07	18.16	3.00
TOTAL	49.9	55.6	54.1	51.4

*4,8,12-TMTD is trimethyltridecanoic acid,
2,6,10,14-TMPD is tetramethylpentadecanoic acid,
3,7,11,14-TMHD is tetramethylhexadecanoic acid, and
7-M-16:0 is 7-methylhexadecanoic acid found in esters after hydrogenation.

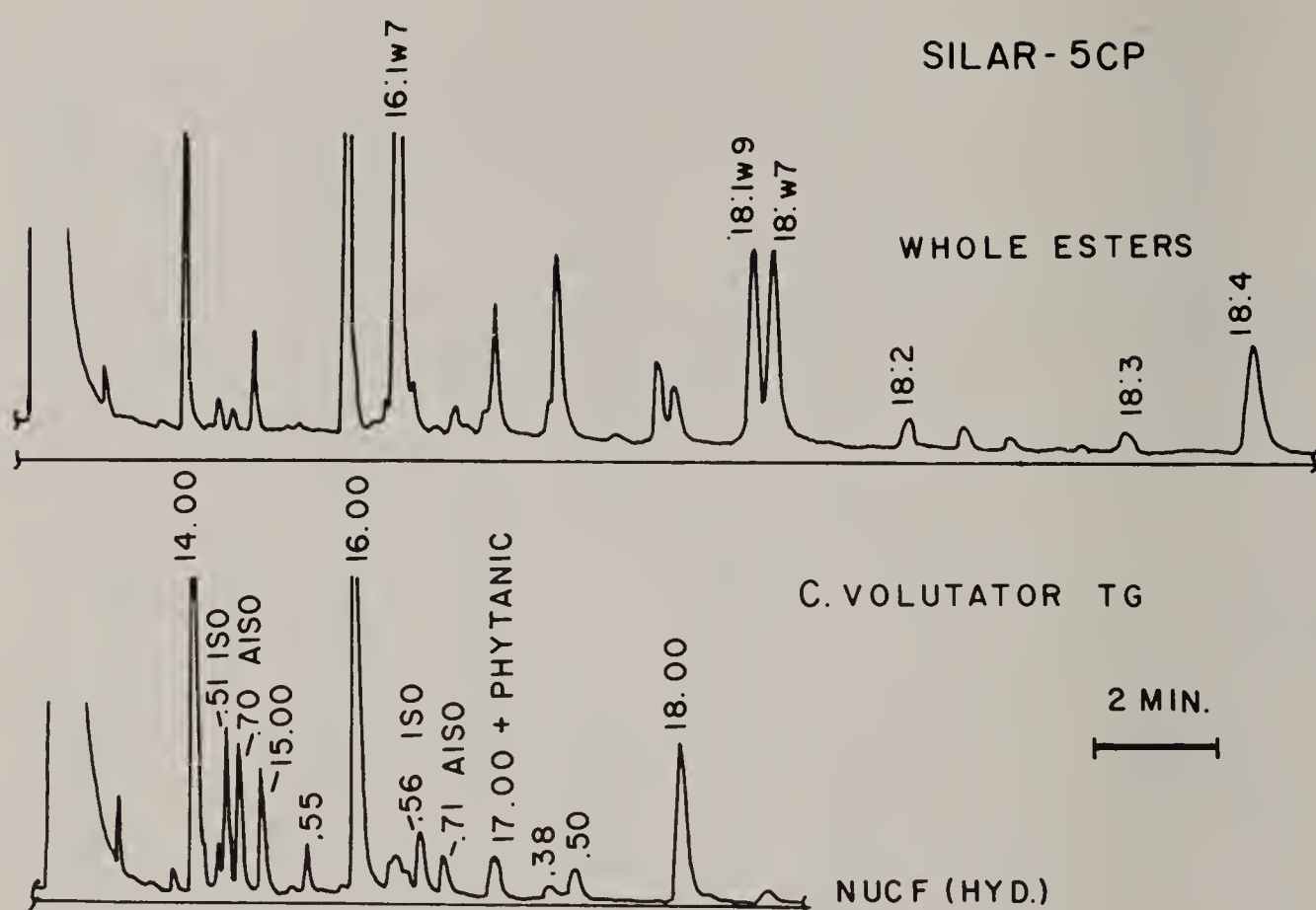


Fig 3. Comparison of parts of GLC charts for the C_{14} - C_{18} methyl esters of fatty acids from triglycerides of lot IV *C. volutator*. Open-tubular column, coating SILAR-5CP, at 170° . The upper section is of whole esters, the lower of the same esters after hydrogenation and 1 treatment with urea. Decimal numbers are FCL values for selected components (see Table III). Note triad peak between 16:0 and *iso* - 17:0 at ECL (16).56 in NUCF fraction.

some mammalian tissues can be associated with sterols (Hradec & Dusek 1968). Recent work on the omnipresent *Desulfovibrio desulfuricans* suggests a local origin for such fatty acids (Boon et al. 1977). The percentage of monoethylenic acids in the total fatty acids from this band was higher than in the other lipid classes, and among the components contributing to this total was a fatty acid tentatively identified as 16:1 ω 9 at 4.95% of the total. If the identification is correct, this is almost a unique occurrence of this acid in animal lipids as the 16:1 group of isomers is normally dominated by the 16:1 ω 7 isomer. The tentative GLC identification is supported by the importance of the probable 14:1 isomer (14:1 ω 9) arising from chain shortening of 16:1 ω 9, which in turn should arise by chain shortening of 18:1 ω 9. Alternatively this lipid could be involved in biosynthesis of monoethylenic fatty acids from saturated acids by one or more pathways which can start from 10:0, for example, with 18:1 ω 9 as the product (Gurr 1974). Traces of a 16:1 ω 3 acid were tentatively identified, also possibly originating in an aberrant fatty acid pathway.

The totals for polyunsaturated fatty acids (Table II) are all very similar but there are quite important differences in detail. The unusual fatty acids 16:2 ω 4, 16:3 ω 4, and 16:4 ω 1 all originate in phytoplankters (Ackman et al. 1968) or seaweeds (Ackman & McLachlan 1977) and cannot as far as is known be formed in animals. Not unexpectedly these acids accumulate in the TG and are much less important in the PL. Some are also observed to be more important in the upper-band fatty acids than in the PL. Conversely the fatty acid 'essential' to mammals (20:4 ω 6) is highest in

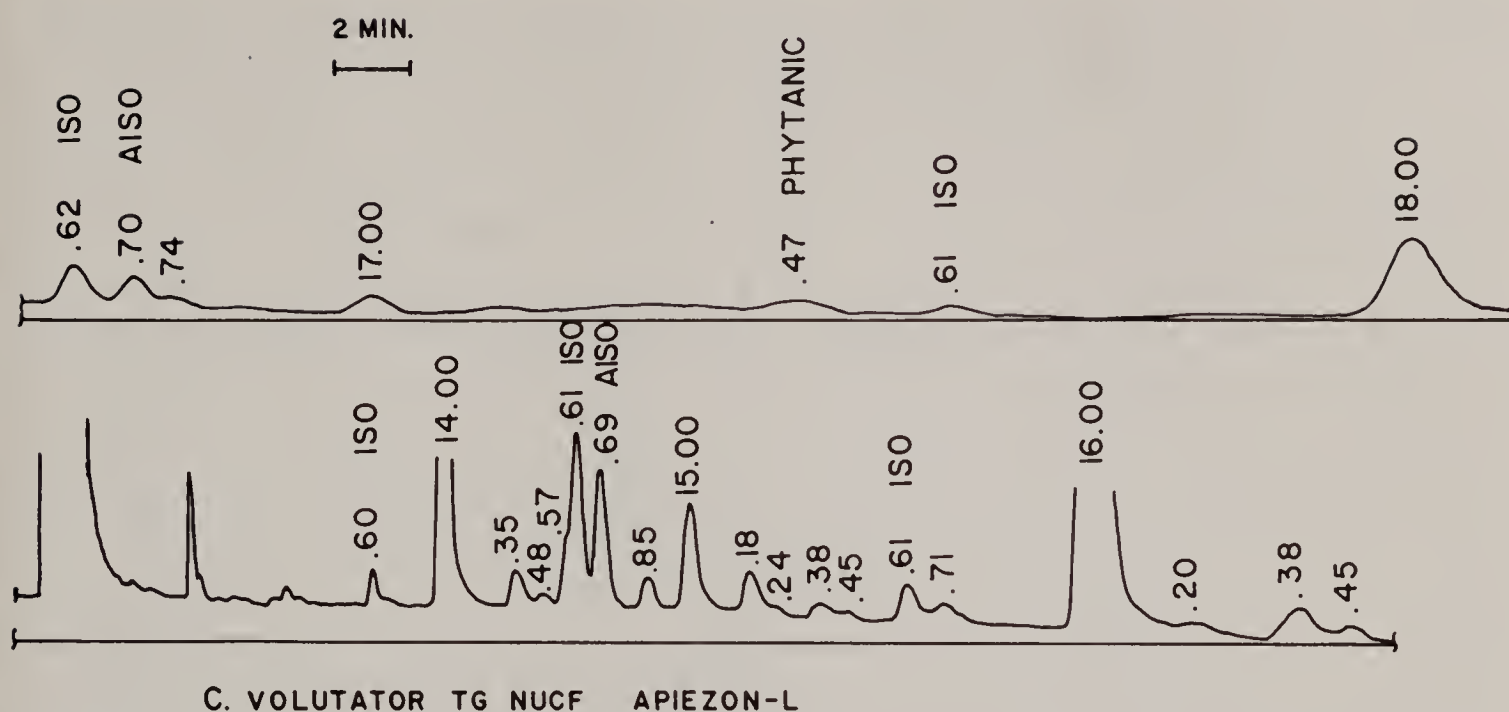


Fig 4. Part of GLC chart for methyl esters of fatty acids from triglycerides of lot IV *C. volutator* after hydrogenation and 1 treatment with urea. Open-tubular column, coating Apiezon-L, at 170°. Decimal numbers are FCL values for selected components (see Table III). Note (16).74 component, possibly a cyclopropanoid acid and compare with (17).38 component in Figure 3. Extra width of phytanic acid peak at (17).47 suggests two stereoisomers. Genuine *iso*-18:0 with ECL of (17).61 appears to be too small to match with peak at ECL (17).50 in Figure 3.

the PL, but is also important in the upper band. The precursor of 20:4 ω 6 is 18:2 ω 6 in both plants and animals, and as in most marine animal lipids (Moreno et al. 1979) does not accumulate (except in this case in the upper band lipid). The successor acid 22:5 ω 6 is also important in the PL. The vital role of 20:5 ω 3 and 22:6 ω 3 in marine PL is most apparent in the percentage figures for this lipid class, arguing for active control of these polyunsaturated acids by the animal (Moreno et al. 1979). On the other hand, in the triglycerides there is an accumulation of 20:5 ω 3 and 18:4 ω 3, both probably of exogenous plant origin, while 22:6 ω 3 is less important. The unusual 21:5 ω 3 component (Mayzaud & Ackman 1978) is also most obvious in the triglycerides, and seems to be present in the PL and TG in proportion to the percentage of 20:5 ω 3. This may be indicative of an exogenous origin for the 21:5 ω 3. It is interesting that freshwater crustaceans need and accumulate 20:5 ω 3 and 22:6 ω 3 (Takahashi & Yamada 1976; Teshima et al. 1976) at reduced levels, although these fatty acids are commonly thought of as 'marine' fatty acids. Their significance in lipids from species living in brackish waters is therefore difficult to evaluate.

Non-methylene-interrupted dienoic fatty acids, (Paradis & Ackman 1977; Pearce & Stillway 1977), did not appear to be present in significant quantities.

Minor and Unusual Fatty Acids

Several fatty acids other than those listed in Table II were apparent in the hydrogenated methyl ester sample from lot II neutral lipids. These were concentrated by urea complex treatment and the same procedure was later applied to the neutral lipids from lot IV. These had been freed of unsaponifiable matter and converted to methyl esters with BCl₃ instead of BF₃ in case cyclopropane structures were present. Retention data for all significant peaks on the liquid phases SILAR-5CP and Apiezan-L are recorded in Table III, cross-referenced where possible since a

Table III. Equivalent chain length data for analyses of minor components concentrated by urea complex treatment of products from hydrogenation of methyl esters of *Cor-ophium volutator* triglycerides (lot IV)

Equivalent chain lengths		Identification	
SILAR-5CP*	Apiezon-L	Structure	Status
13.53	13.60	Iso 14:0	Firm
14.00	14.00	14:0	Firm
14.15	14.35	4,8,12-trimethyltridecanoate	Firm
14.42(20%)	14.48	4-methyltetradecanoate	Possible
14.42(80%)	14.85	Unknown	
14.51	14.61	Anteiso 15:0	Firm
14.70	14.69	Iso 15:0	Firm
15.00	15.00	15:0	Firm
15.37	14.72	Cyclopropane	Possible
15.55	15.61	Iso 16:0	Firm
15.90	16.38	2,6,10,14 tetramethylpentadecanoate	Possible
16.00	16.00	16:0	Firm
16.31	16.38	7-methylhexadecanoate	Possible
16.36	15.71?	Cyclopropane	Possible
16.43	16.45	4-methylhexadecanoate	Possible
16.52	16.62	Iso 17:0	Firm
15.72	16.71	Anteiso 17:0	Firm
17.00 (50%)	17.00	17:0	Firm
17.00 (50%)	17.47		
		3,7,11,15 tetramethylhexadecanoate	Firm
17.38	16.74	Cyclopropane	Possible
17.50(80%)	17.17?	?	?
17.50 (20%)	17.61	Iso 18:0	Possible
?	14.57	?	?
?	15.18	?	?
?	15.24	?	?
?	15.38	?	?
?	15.45	?	?
?	16.20	2-methylhexadecanoate	Possible

*SILAR-5CP column No. 6153 and Apiezon-L column 907, both operated at 170°.

number of components coincide on the one column or the other. The complete identification of all of these components was not possible without further work, but the reproducibility of the chromatograms from 2 separate lots of *C. volutator*, with lipids converted to methyl esters by different reactions, suggests that the non-specific component data are worth recording as a starting point for future research. The Apiezon-L chromatogram chart showed several peaks not accounted for in the SILAR-5CP analysis. Because of the special reproducibility of retention data on Apiezon-L (Ackman 1972) these unknowns are included in Table III.

This cross-check on polar and non-polar columns is important in establishing the presence or absence of certain components. The component with ECL of 17.50 on SILAR-5CP could have been mistaken entirely for iso 18:0, but could not be accounted for quantitatively on Apiezon-L (ECL 17.61). This loss of the larger part of the peak argues for a degree of polarity, and a cyclopropanoid fatty acid was initially suspected, but authentic methyl 9,10-methylenehexadecanoate had an ECL on the SILAR column of 17.38 and would have emerged at about 16.74 on this Apiezon-L column (experimental on AP-L 907; see also literature data summarized by Ackman, 1972). Careful comparison of retention times showed that this unknown of ECL 17.50 was virtually absent among the NUCF components of the phospholipids, although the nearby suspected plasmalogen derivative emerging at ECL 17.55 on SILAR-5CP was confined to the phospholipids. On the other hand the corresponding peak of triglyceride origin at ECL 15.55 on SILAR-5CP could be verified as iso 16:0 by the same size peak on AP-L at ECL 15.61. Morris (1973) records a component listed as iso-18:0 for certain similar crustacea, suggesting that the unknown may be widespread in such lipids.

Other details were supported by circumstantial evidence, such as the width of the phytanic acid (3,7,11,15-tetramethylhexadecanoic) peak on Apiezon-L being greater than expected from that of adjacent single components. Two stereoisomers are therefore likely (Ackman 1972). The methyl esters of phytanic acid and 4,8,12-trimethyltridecanoic acid were definitely present in both polar lipid and triglyceride, but methyl 2,6,10,14-tetramethylpentadecanoate was obvious only in the triglycerides.

The methyl-branched fatty acids other than iso and anteiso are of considerable interest (possibly the triad peak of Fig 3), but their identification by gas-liquid chromatography only (Ackman et al. 1972; Smith & Duncan, 1979) is difficult. The cyclopropane fatty acids, if the identifications are correct, are clearly of bacterial origin (Brian et al. 1972; Oliver & Colwell 1973; O'Leary 1975; Lambert & Moss 1977; Ikemoto et al. 1978), but the amounts are very minor. There is no implication that the mud-dwelling *P. volutator* subsists on exogenous bacteria directly, but it is possible that it has gut bacteria capable of freeing or accumulating materials from plant detritus either directly or indirectly, in the latter case by stripping off the exoflora.

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A PRELIMINARY CHECKLIST OF MARINE FAUNA OF MINAS BASIN AND MINAS CHANNEL*

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Introduction

Intensive sampling in Minas Basin and Minas Channel since 1974 revealed the presence of many taxa previously unrecorded from the area. These records, as well as others dating before 1974, comprise this checklist which includes species from phyla representing both vertebrates and invertebrates.

Data have been drawn mainly from unpublished reports and are directly attributable to the efforts of Summer Job Corps Program employees, sponsored by Canada Manpower and Immigration. Reported unspecified genera were not listed. Among these are *Pycnophyes*, *Dinophilis*, and *Tenellia*, all first records for Bay of Fundy and awaiting specific identification.

Protozoan systematic levels follow the hierarchy and nomenclature of Barnes (1969), invertebrate and vertebrate metazoans follow those of Gosner (1971) and Blair et al. (1957) respectively. Each entry includes one or more abbreviated credits. All probable sources of information on Minas Basin and Minas Channel fauna and additional major references, useful as guides, appear in the bibliography.

Much confusion exists in the primary literature regarding synonymic priority, there will undoubtedly be disagreement about the choice of names, and it is inevitable that some diagnoses are disputable. It is important, therefore, that users of this list contribute their opinions and suggestions by writing to me.

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Check List

The sources given report the presence of designated taxa in Minas Basin and Minas Channel, and are indicated by the following abbreviations.

AUM	Acadia University Museum
B77	Bleakney, 1977
Bai67	Bailey, 1967
BaiB67	Bailey and Bleakney, 1967
BBr78	Bleakney and Bromley, 1978

* Issued as NRCC No. 17747

BM74	Bleakney and Mustard, 1974
BMc73	Bleakney and McAllister, 1973
Bo52	Bousfield, 1952
Boa78	Boates, 1978
BoL60	Bousfield and Leim, 1960
Br78	Bromley, 1978
BS78	Bleakney and Saunders, 1978
Ca66	Calder, 1966
D79	Daborn, 1979
FeR77	Featherstone and Risk, 1977
Fr74	Frank, 1974
FrB76	Frank and Bleakney, 1976
FrB78	Frank and Bleakney, 1978
FT77	Fuller and Trevors, 1977
G78	Gratto, 1978
J58	Jermolajev, 1958
Jo30	Johansen, 1930
Mc79	McCurdy, 1979
Me71	Meyer, 1971
N74	Norenburg, 1974
N76	Norenberg, 1976
P79	Petersen, 1979
Pen78	Pennachetti, 1978
PoC67	Powell and Crowell, 1967
PP77	Petersen and Petersen, 1977
R79	Robinson, 1979
Wa79	Waugh, 1979
Wh01	Whiteaves, 1901
Y77	Yoe, 1977

PHYLUM PROTOZOA

Subphylum **Sarcomastigophora**

Superclass **Sarcodina**

Order **Foraminiferida**

Family **Rzehakinidae**

Miliammina fusca Brady 1870. Br78; BBr78

Family **Trochamminidae**

Jadammina polystoma Bartenstein and Brand 1938. Br78; BBr78

Trochammina inflata (Montagu 1808). Br78; BBr78

Family **Lituolidae**

Ammotium salsum (Cushman and Brönnimann 1948). Br78; BBr78

Haplophragmoides bonplandi Todd and Brönnimann 1957. Br78; BBr78

Family **Elphidiidae**

Criboelthidium excavatum (Terquem 1876). Br78; BBr78

Family **Rotaliidae**

Ammonia beccarii (Linnaeus 1758). Br78; BBr78

Class **Ciliata**

Order **Holotricha**

Family **Folliculinidae**

Semifolliculina gigantus. Bai67

PHYLUM PORIFERA

Class **Calcarea**

Family **Homocoelidae**

Leucosolenia botryoides (Fleming) FT77

PHYLUM PORIFERA

Class **Desmospongiae**Order **Haplosclerida**Family **Desmacidonidae**

Desmacidon palmata Johnston. Wh01

Isodictya palmata (Lamark) Bowerbank 1858. BM74

Family **Haliclonidae**

Haliclona oculata (Linnaeus 1759). Wh01; BM74; FT77

Order **Poecilosclerida**Family **Microcionidae**

Microciona prolifera (Ellis & Solander 1786). BM74

Order **Halichondrida**Family **Halichondridae**

Halichondria panicea (Pallas 1766). BM74; FT77

Order **Hadromerida**Family **Suberitidae**

Polymastia robusta Verrill 1873. BM74

Family **Clionidae**

Cliona celata Grant 1826. BM74

PHYLUM CNIDARIA

Class **Hydrozoa**Order **Athecata**Family **Hydridae**

Protohydra leuckarti Greeff 1870. Br78; BBr78

Family **Corymophiidae**

Corymorpha pendula Agassiz 1862. BoL60; FT77

Family **Tubulariidae**

Tubularia crocea (Agassiz 1862). BoL60

Tubularia indivisa Linnaeus 1767. PP77

Tubularia larynx Ellis & Solander 1786. PP77

Tubularia spectabilis (Agassiz 1862). BoL60

Family **Acaulidae**

Acaulis primarius Stimpson 1854. BoL60

Family **Corynidae**

Coryne tubulosa (Sars 1835). PP77

Staurocoryne producta (Wright). PP77

Family **Clavidae**

Clava multicornis (Forskäl 1775). PP77

Family **Hydractiniidae**

Hydractinia echinata Fleming 1828. Ca66; FT77; PP77

Hydractinia valens Fraser 1941. FT77

Podocoryne carnea Sars 1846. BoL60

Family **Bougainvilliidae**

Nemopsis bachei L. Agassiz 1849. BoL60; Pen78

Family **Pandeidae**

Leuckartiara octona (Fleming 1823). PP77

Family **Eudendriidae**

- Eudendrium arbusculum* Wright 1859. PP77
- Eudendrium capillare* Alder 1856. PP77
- Eudendrium insigne* Hincks 1861. PP77
- Eudendrium rameum* (Pallas 1766). PP77
- Eudendrium ramosum* Linnaeus 1758. PP77
- Eudendrium tenellum* Allman 1877. PP77
- Eudendrium tenue* Agassiz 1865. BoL60

Order **Thecata**

Family **Campanulariidae**

- Campanularia verticillata* (Linnaeus 1758). BoL60; PP77
- Laomedea dichotoma* (Linnaeus 1758). BoL60; PP77; P79
- Laomedea flexuosa* Alder. PP77
- Laomedea gracilis* (Sars 1851). PP77
- Laomedea geniculata* (Linnaeus 1758). BoL60; PP77
- Laomedea loveni* (Allman 1859). BoL60; PP77

Family **Campanulinidae**

- Campanulina lacerata* (Johnston). PP77
- Cuspidella costata* Hincks 1868. PP77
- Cuspidella grandis* Hincks 1864. PP77
- Cuspidella humilis* (Alder 1862). PP77
- Calycella syringa* (Linnaeus 1767). BoL60; PP77

Family **Halecidae**

- Halecium beani* (Johnston 1847). BoL60
- Halecium halecinum* (Linnaeus 1767). BoL60

Family **Sertularidae**

- Abietinaria abietina* (Linnaeus 1758). BoL60
- Diphasia fallax* (Johnston 1847). BoL60
- Diphasia rosacea* (Linnaeus 1758). BoL60
- Dynamena pumila* (Linnaeus 1758). PP77
- Hydrallmania falcata* (Linnaeus 1758). BoL60; PP77
- Sertularella rugosa* (Linnaeus 1758). BoL60
- Sertularella tricuspidata* (Alder 1856). BoL60
- Sertularia cupressina* Linnaeus 1758. PP77
- Thuiaria cupressina* (Linnaeus 1758). BoL60
- Thuiaria similis* (Clark 1876). BoL60

Family **Plumularidae**

- Antennularia americana* Nutting 1900. BoL60
- Antennularia antennina* (Linnaeus 1767). BoL60

Class **Anthozoa**

Subclass **Zoantharia**

Order **Actiniaria**

Family **Edwardsiidae**

- Edwardsia elegans* Verrill 1869. R79; Wa79
- Nematostella vectensis* Stephenson 1935. Bai67; F74; FB76; N76; BBr78; Br78; FB78; Pen78

Family **Actinidae**

- Tealia felina* (Linnaeus 1767). R79; Wa79

Subclass **Ceriantipatharia**

Order **Ceriantharia**

Family **Cerianthidae**

- Cerianthus borealis* Verrill. FT77

PHYLUM CTENOPHORA

Class **Tentaculata**Order **Cydippida**Family **Pleurobrachiidae**

Pleurobrachia pileus (Fabricius 1780). Pen78

PHYLUM PLATYHELMINTHES

Class **Turbellaria**Order **Acoela**Family **Convolutidae**

Neochildia fusca Bush 1975. N76; BBr78; Br78

Order **Alloeocoela**Suborder **Seriata**Family **Monocelididae**

Monocelis durhami Hyman. BBr78; Br78

Order **Polycladida**Suborder **Acotylea**Section **Schematommata**Family **Leptoplanidae**

Euplana gracilis (?) (Girard 1850). Pen78

Notoplana atomata (Müller 1776). FT79; Boa78

PHYLUM RHYNCHOCOELA (NEMERTEA)

Class **Anopla**Order **Paleonemertea**Family **Cephalothricidae**

Procephalothrix spiralis (Coe 1930). N74

Order **Heteronemertea**Family **Lineidae**

Cerebratulus lacteus (Leidy 1851). N74; Boa78; G78

Lineus bicolor Verrill 1892. N74

Lineus ruber (Müller 1771). N74

Lineus socialis (Leidy 1855). N74

Lineus viridis (Fabricius) Johnston 1865. N76; BBr78; Br78

Class **Enopla**Order **Hoplonemertea**Suborder **Monostylifera**Family **Amphiporidae**

Amphiporus lactifloreus (Johnston 1828). N74, 76

Family **Tetrastemmatidae**

Prostomatella obscura (Schultz 1851). N76; BBr78; Br78

PHYLUM ECTOPROCTA (BRYOZOA)

Class **Gymnolaemata**Order **Ctenostomata**Family **Alcyonidiidae**

Alcyonidium polyoum (Hassall 1841). PoC67

Family **Flustrellidridae**

Flustrellidra hispida (Fabricius 1780). PoC67

Family **Vesicularidae**

Bowerbankia gracilis Leidy 1855. Bai67; BBr78; Br78

Order **Cheilostomata**

Suborder **Anasca**

Family **Membraniporidae**

Conopeum reticulum (Linnaeus 1767). PoC67

Family **Electridae**

Electra crustulenta (Pallas 1766). PoC67

Electra crustulenta (Pallas) var. *arctica* Borg 1931. PoC67

Electra monostachys (Busk 1854). PoC67

Electra pilosa (Linnaeus 1758). PoC67

Family **Flustridae**

Flustra foliacea (Linnaeus 1738). BoL60; PoC67; FT77

Family **Calloporidae**

Callopora whiteavesii Norman 1903. PoC67

Callopora aurita (Hincks 1877). PoC67

Family **Cribrilinidae**

Cribrilina cryptoecium Norman 1903. PoC67

Cribrilina punctata (Hassall 1841). PoC67

Suborder **Ascophora**

Family **Escharellidae**

Hippothoa hyalina (Linnaeus 1767). PoC67

Escharella immersa (Fleming 1828). PoC67

Family **Cheiloporinidae**

Cryptosula pallasiana (Moll 1803). PoC67

PHYLUM **CHAETOGNATHA**

Sagitta elegans Verrill 1873. J58; BoL60; Pen78

PHYLUM **BRACHIOPODA**

Class **Articulata**

Order **Terebratulida**

Family **Cancellothyrididae**

Terebratulina septentrionalis (Couthouy). BoL60

PHYLUM **MOLLUSCA**

Class **Amphineura**

Subclass **Polyplacophora**

Order **Neoloricata**

Family **Ischnochitonidae**

Ischnochiton albus (Linnaeus 1767). BoL60

Ischnochiton ruber (Linnaeus 1767). BoL60; R79; Wa79

Class **Gastropoda**

Subclass **Prosobranchia**

Order **Archeogastropoda**

Family **Fissurellidae**

Puncturella noachina (Linnaeus 1771). BoL60

Family **Acmaeidae**

Acmaea testudinalis Müller 1776. BoL60; FT77; Y77; R79; Wa79

Family **Trochidae**

Margarites helycinus (Phipps 1774). BoL60

Order **Mesogastropoda**Family **Lacunidae**

Lacuna vincta (Montagu 1803). BoL60; R79; Wa79

Family **Littorinidae**

Littorina littorea (Linnaeus 1758). BoL60; Bai67; N76; FT77; Y77; BBr78; Br78; R79; Wa79

Littorina obtusata (Linnaeus 1758). BoL60; FT77

Littorina saxatilis (Olivi 1792). BoL60; Bai67; N76; FT77; BBr78; Br78

Family **Hydrobiidae**

Hydrobia totteni (Morrison 1954). BoL60; Bai67; N76; FT77; Y77; BBr78; Br78

Family **Rissoidae**

Onoba aculeus (Gould 1841). BoL60

Family **Skeneopsidae**

Skeneopsis planorbis (Fabricius 1780). BoL60

Family **Calyptraeidae**

Crepidula fornicata Linnaeus 1767. Wh01; BoL60; FT77; Y77; R79; Wa79

Crepidula plana Say 1822. BoL60; FT77

Crucibulum striatum (Say 1826). BoL60; FT77

Family **Naticidae**

Lunatia heros (Say 1822). BoL60; FT77; Y77; Boa78; G78

Lunatia triseriata (Say 1826). BoL60; FT77; Y77

Polinices immaculatus (Totten 1835). BoL60

Family **Lamellariidae**

Velutina laevigata (Linnaeus 1767). BoL60

Order **Neogastropoda**Family **Muricidae**

Boreotrophon clathratus (Linnaeus 1758). FT77

Nucella lapillus Linnaeus 1758. BoL60; FT77; Y77

Urosalpinx cinerea (Say 1822). BoL60; FT77; Y77

Family **Columbellidae**

Mitrella lunata (Say 1826). BoL60; FT77; R79; Wa79

Family **Buccinidae**

Buccinum totteni (Stimpson 1865). FT77

Buccinum undatum Linnaeus 1761. BoL60; FT77; Boa78

Colus stimpsoni (Mörch 1867). BoL60; FT77

Neptunea decemcostata (Say 1826). BoL60; FT77

Family **Nassariidae**

Ilyanassa obsoleta (Say 1822). BoL60; Bai67; FT77; Y77; BBr78; Boa78; Br78; G78; Pen78

Nassarius trivittatus (Say 1822). BoL60; FT77; Y77; G78; R79; Wa79

Family **Cancellariidae**

Admete couthouyi (Jay 1839). R79; Wa79

Family **Turridae**

Oenopota bicarinata Couthouy 1838. BoL60; R79; Wa79

Oenopota nobilis (Möller 1842). BoL60

Subclass **Opisthobranchia**Order **Cephalaspidea**Family **Retusidae**

Retusa obtusa (Montague 1807). BoL60; FT77

Family **Scaphandridae***Cylichna alba* (Brown 1827). BoL60Order **Sacoglossa**Suborder **Polybranchiacea**Family **Hermaeidae***Alderia modesta* (Lovén 1844). Bai67; BBai67; BBr78; Br78*Stiliger fuscatus* (Gould 1870). B77; BBr78; Br78Suborder **Elysiacea**Family **Elysiidae***Elysia chlorotica* (Gould 1870). Bai67; BaiB67; BBr78; Br78Order **Nudibranchia**Suborder **Doridacea**Family **Goniodorididae***Ancula gibbosa* (Risso 1818). Me71Family **Onchidorididae***Acanthodoris pilosa* (Müller 1776). Me71; B77; FT77; R79; Wa79*Onchidoris aspera* Alder and Hancock 1842. Me71; B77*Onchidoris bilamellata* Linnaeus 1767. Me71; BS78Family **Polyceridae***Polycera dubia* (Sars 1829). Me71; B77Family **Cadlinidae***Cadlina laevis* (Linnaeus 1767). B77Suborder **Dendronotacea**Family **Dendronotidae***Dendronotus frondosus* (Ascanius 1774). Me71; B77Family **Dotonidae***Doto coronata* (Gmelin 1791). Me71; B77Suborder **Aeolidacea**Family **Coryphellidae***Coryphella stellata* (Stimpson 1853). Me71; B77*Coryphella rufibranchialis* (Johnston 1832). Me71; B77Family **Eubranchidae***Eubranchus olivaceus* (O'Donoghue 1922). Me71*Eubranchus pallidus* (Alder & Hancock 1842). B77*Eubranchus tricolor* (Forbes 1838). B77Family **Cuthonidae***Catriona aurantia* (Alder & Hancock 1842). B77*Cuthona concinna* Alder and Hancock 1843. Me71*Tenellia fuscata* Gould 1870. B77*Tergipes tergipes* (Forsskål 1775). Me71; B77Family **Facelinidae***Facelina bostoniensis* (Couthouy 1838). Me71; B77Family **Aeolidiidae***Aeolidia papillosa* (Linnaeus 1761). Me71; B77Family **Pyramidellidae***Odostomia bisuturalis* (Say 1821). BoL60*Odostomia trifida* (Totten 1834). BoL60*Turbonilla elegantula* Verrill 1882. Boa78*Turbonilla interrupta* (Totten 1835). BoL60; FT77

Class **Pelecypoda**Subclass **Prionodesmata**Order **Protobranchia**Family **Nuculidae***Nucula proxima* Say 1822. BoL60; R79; Wa79*Yoldia myalis* (Couthouy 1838). FT77Subclass **Pteriomorphia**Order **Pteroconchida**Family **Mytilidae***Crenella glandula* (Totten 1834). BoL60; FT77; R79; Wa79*Geukensia demissa* (Dillwyn 1817). Wh01; Bai67; FT77; BBr78; Br78*Modiolus modiolus* (Linnaeus 1758). BoL60; FT77*Musculus corrugatus* Stimpson 1851. BoL60; R79; Wa79*Musculus discors* Linnaeus 1767. BoL60*Musculus discors* var. *laevigatus* (Gray 1824). BoL60*Mytilus edulis* Linnaeus 1758. BoL60; FT77; BBr78; Br78; G78Family **Pectinidae***Chlamys islandica* (Müller 1776). BoL60*Placopecten magellanicus* (Gmelin 1791). BoL60; FT77Family **Anomiidae***Anomia squamula* Linnaeus 1758. BoL60; FT77Subclass **Teleodesmata**Order **Heterodontida**Family **Astartidae***Astarte castanea* Say 1822. Wh01; BoL60; R79; Wa79*Astarte subaequilatera* Sowerby 1855. BoL60; FT77*Astarte undata* Gould 1841. Wh01; BoL60; FT77Family **Carditidae***Venericardia borealis* Conrad 1831. BoL60; FT77Family **Arcticidae***Arctica islandica* (Linnaeus 1767). BoL60; FT77Family **Veneridae***Gemma gemma* (Totten 1834). BoL60; Bai67; FT77; Y77; BBr78; Boa78; Br78; G78; R79; Wa79*Mercenaria mercenaria* (Linnaeus 1758). FT77*Pitar morrhuanus* (Linsley 1848). BoL60Family **Petricolidae***Petricola pholadiformis* (Lamarck 1818). BoL60; FT77; Y77; G78; R79; Wa79Family **Mactridae***Anatina anatina* (Spengler 1802). FT77*Spisula solidissima* (Dillwyn 1817). BoL60; FT77Family **Tellinidae***Macoma balthica* (Linnaeus 1758). BoL60; FeR77; FT77; Y77; Boa78; G78; R79; Wa79Family **Solenidae***Ensis directus* (Conrad 1843). BoL60; FeR77; FT77; Y77; Boa78; R79; Wa79Family **Myidae***Mya arenaria* Linnaeus 1758. BoL60; FeR77; FT77; Y77; BBr78; Boa78; Br78; G78; R79; Wa79Family **Hiatellidae***Hiatella arctica* (Linnaeus 1767). BoL60; R79; Wa79*Hiatella striata* Fleury 1802. BBr78; Br78

Family **Pholadidae***Barnea truncata* Say 1822. BoL60; Y77*Zirfaea crispata* (Linnaeus 1758). R79; Wa79Subclass **Anomalodesmata**Order **Eudesmodontida**Family **Pandoridae***Pandora gouldiana* Dall 1886. BoL60; FT77; Y77; R79; Wa79Family **Lyonsiidae***Lyonsia hyalina* (Conrad 1831). BoL60; R79; Wa79Family **Periplomatidae***Periploma leanum* (Conrad 1831). BoL60Class **Cephalopoda**Subclass **Coleoidea**Order **Teuthidida**Family **Loliginidae***Loligo pealei* Lesueur 1821. BoL60; FT77

PHYLUM ANNELIDA

Class **Polychaeta**Order **Phyllodocida**Family **Phyllodocidae***Anaitides (?) catenula* (Verrill 1873). PP77; P79*Anaitides groenlandica* Ørsted 1842. FT77; PP77; P79; R79; Wa79*Anaitides maculata* (Linnaeus 1767). BoL60; FT77; PP77; R79; Wa79*Anaitides mucosa* Ørsted 1843. Boa78; G78; R79; Wa79*Eteone heteropoda* Hartman 1951. FT77; PP77; BBr78; Boa78; Br78; G78*Eteone lactea* Calparède 1868. PP77; G78*Eteone longa* (Fabricius 1780). PP77; BBr78; Boa78; Br78; G78; R79; Wa79*Eulalia bilineata* Johnston 1840. BoL60; PP77*Eulalia viridis* (Linnaeus 1767). PP77; R79; Wa79*Eumida sanguinea* (Ørsted 1843). PP77Family **Polynoidae***Gattyana cirrosa* (Pallas 1766). PP77*Harmothoë extenuata* (Grube 1840). R79; Wa79*Harmothoë imbricata* (Linnaeus 1767). BoL60; FT77; PP77; R79; Wa79*Lepidonotus squamatus* (Linnaeus 1758). FT77; PP77; R79; Wa79Family **Sigalionidae***Pholoe minuta* (Fabricius 1780). PP77*Pholoe tecta* Stimpson 1854. P79*Sigalion arenicola* Verrill 1879. G78Family **Glyceridae***Glycera dibranchiata* Ehlers 1868. FT77; PP77; Y77; Boa78; G78Family **Goniadidae***Ophioglycera gigantea* Verrill 1885. Mc79Family **Nephtyidae***Aglaophamus neotenus* Noyes. R79; Wa79*Nephtys buccera* Ehlers 1868. G78*Nephtys caeca* (Fabricius 1780). FT77; PP77; Y77; Boa78; G78; R79; Wa79Family **Syllidae***Eusyllis blomstrandii* Malmgren 1867. G78*Exogone dispar* (Webster 1879). PP77; G78; R79; Wa79*Exogone hebes* (Webster and Benedict 1884). PP77; G78; R78; Wa79*Syllides longocirrata* Ørsted 1845. PP77

Syllis cornuta Rathke 1843. G78

Syllis gracilis Grube 1840. G78

Family **Hesionidae**

Microphthalmus (?) *aberrans* (Webster and Benedict 1887). PP77

Microphthalmus scelkowi Mecznirow 1865. PP77

Family **Nereidae**

Nereis diversicolor Müller 1776. PP77; BBr78; Br78

Nereis pelagica Linnaeus 1758. BoL60; PP77

Nereis virens Sars 1835. BoL60; FT77; PP77; Y77; Boa78; G78; R79; Wa79

Order **Capitellida**

Family **Capitellidae**

Capitella capitata (Fabricius 1780). PP77; G78

Heteromastus filiformis (Claparède 1864). FT77; PP77; Y77; BBr78; Boa78; Br78; G78; R79; Wa79

Notomastus latericeus Sars 1851. R79; Wa79

Family **Arenicolidae**

Arenicola marina (Linnaeus 1758). Y77

Family **Maldanidae**

Clymenella torquata (Leidy 1855). FT77; FeR77; PP77; Y77; Boa78; G78; R79; Wa79

Clymenella zonalis (Verrill 1874). FT77; PP77; G78; R79; Wa79

Family **Opheliidae**

Ophelia bicornis Savigny 1818. PP77

Ophelia limacina Rathke. G78

Order **Sternaspida**

Family **Sternaspidae**

Sternaspis scutata (Renier 1807). BoL60

Order **Spionida**

Family **Spionidae**

Polydora ciliata (Johnston 1838). PP77; Y77

Polydora ligni Webster 1879. FT77; PP77; BBr78; Br78; G78; R79; Wa79

Pygospio elegans Claparède 1863. FT77; PP77; Y77; BBr78; Boa78; Br78; G78.

Scolecopides viridis (Verrill 1873). PP77; Y77; G78

Scolelepis squamata (Müller 1789). R79; Wa79

Spio filicornis (Müller 1766). R79; Wa79

Spiophanes bombyx (Claparède 1870). FT77; PP77; Boa78; G78

Spiophanes wigleyi Pettibone 1962. FeR77; Y77

Spio setosa Verrill 1873. Y77; G78

Streblospio benedicti Webster 1880. FT77; PP77; BBr78; Boa78; Br78; G78; R79; Wa79

Family **Paronidae**

Aricidea suecica Eliason 1920. PP77; G78; R79; Wa79

Paraonis fulgens (Levinsen 1883). Y77; G78

Paraonis lyra Southern 1914. PP77

Family **Sabellariidae**

Sabellaria vulgaris Verrill 1873. BMc73; PP77; Y77; R79; Wa79

Order **Eunicida**

Family **Lumbrinereidae**

Lumbrineris fragilis (Müller 1776). G78; R79; Wa79

Lumbrineris latreilli (Audouin & Milne-Edwards 1833). PP77

Lumbrineris tenuis (Verrill 1873). Mc79; Wa79

Family **Dorvilleidae***Protodorvillea kefersteini* (McIntosh 1869). G78; Mc79; Wa79*Schistomeringos* (+ *Stauronereis*) *caeca* (Webster & Benedict 1884). PP77*Stauronereis caecus* (Webster and Benedict 1884). R79; Wa79Order **Ariciida**Family **Orbiniidae***Naineris quadricuspida* (Fabricius 1780). PP77*Orbinia ornata* (Verrill 1873). BoL60; G78*Orbinia swani* Pettibone 1957. Y77*Scoloplos fragilis* (Verrill 1873). FT77; BBr78; Br78; G78*Scoloplos armiger* (Müller 1776). FT77; PP77; Boa78; G78Order **Cirratulida**Family **Cirratulidae***Caulleriella fragilis* (Leidy 1855). PP77*Chaetozone setosa* Malmgren 1867. PP77; Boa78; G78; R79; Wa79*Cirratulus cirratus* (Müller 1776). PP77; R79; Wa79*Dodecaceria concharum* Ørsted 1843. PP77*Tharyx acutus* Webster and Benedict 1887. FT77; PP77; Pen78; R79; Wa79Order **Terebellida**Family **Ampharetidae***Amphicteis gunneri* (Sars 1835). Y77*Asabellides oculata* Webster 1879. PP77; G78Family **Terebellidae***Amphitrite cirrata* Müller 1771. PP77; G78*Amphitrite figulus* (Dalyell). R79; Wa79*Amphitrite ornata* (Leidy 1855). PP77*Amphitrite johnstoni* Malmgren 1866. FT77*Nicolea venustula* (Montagu 1818). PP77; R79; Wa79*Polycirrus phosphoreus* Verrill 1880. PP77; R79; Wa79*Polycirrus* ? *eximius* (Leidy 1855). PP77*Pista maculata* (Dalyell 1853). PP77Family **Flabelligeridae***Pherusa affinis* (Leidy 1855). R79; Wa79Order **Sabellida**Family **Sabellidae***Fabricia sabella* (Ehrenberg 1836). PP77; BBr78; Boa78; Br78; G78*Manayunkia aestuarina* (Bourne 1883). PP77; BBr78; Br78*Potamilla neglecta* (Sars 1851). PP77*Potamilla reniformis* (Leuckart 1849). PP77; R79; Wa79Family **Serpulidae***Circeis spirillum* (Linnaeus 1758). PP77Class **Oligochaeta**Order **Plesiopora**Family **Tubificidae***Isochaeta hamata* (Moore 1905). BBr78; Br78*Peloscolex benedini* (Udekem 1835). BBr78; Br78; G78*Tubifex pseudogaster* (Dahl 1960). BBr78; Br78PHYLUM **SIPUNCULA***Phascolopsis gouldi* (Pourtales 1851). R79; Wa79

PHYLUM ARTHROPODA

Subphylum **Pycnogonida**Class **Pantopoda**Family **Nymphonidae***Nymphon rubrum* Hodge 1865. BoL60Family **Phoxichilidiidae***Phoxichilidium femoratum* (Rathke 1799). BoL60Family **Pycnogonidae***Pycnogonum littorale* (Strom 1762). BoL60; FT77Subphylum **Mandibulata**Class **Crustacea**Subclass **Branchiopoda**Order **Cladocera**Family **Polyphemidae***Podon leuckarti* Sars 1862. Pen78Subclass **Copepoda**Order **Calanoida**Family **Calanidae***Calanus finmarchicus* Gunnerus 1770. J58; Pen78Family **Pseudocalanidae***Pseudocalanus minutus* (Kröyer 1849). J58Family **Centropagidae***Centropages hamatus* (Lilljeborg 1853). J58Family **Diaptomidae***Pseudodiaptomus coronatus* Williams 1906. J58; Pen78Family **Temoridae***Eurytemora herdmanni* Thompson & Scott 1898. J58Family **Acartiidae***Acartia tonsa* Giesbrecht 1889. J58Order **Harpacticoida**Family **Thalestridae***Parathalestris croni* (Kröyer) 1845. Pen78Order **Cyclopoida**Family **Oithonidae***Oithona similis* Claus 1866. J58Subclass **Cirripedia**Order **Thoracica**Suborder **Balanomorpha**Family **Balanidae***Balanus balanoides* (Linnaeus 1767). BoL60; FT77*Balanus balanus* (Linnaeus 1758). BoL60; Y77*Balanus crenatus* Bruguiere 1789. BoL60*Balanus hameri* (Ascanius 1761). BoL60*Balanus improvisus* Darwin 1854. Bo52; BoL60Subclass **Malacostraca**Superorder **Peracarida**Order **Cumacea**Family **Leuconidae***Eudorella truncatula* (Bate 1856). BoL60; FT77; G78

Family **Lampropidae***Lamprops quadriplicata* Smith 1879. BoL60Family **Diastylidae***Diastylis quadrispinosa* Sars 1871. AUM*Diastylis sculptus* Sars 1871. BoL60; FT77*Oxyurostylis smithi* Calman 1912. BoL60; FT77; Boa78; G78; R79; Wa79Order **Tanaidacea**Family **Paratanaidae***Leptognatha caeca* (Harger 1878). G78; R79; Wa79Order **Isopoda**Suborder **Anthuridea**Family **Anthuridae***Ptilanthura tenuis* Harger 1879. AUM; BoL60Suborder **Flabellifera**Family **Cirolanidae***Cirolana polita* (Stimpson 1853). BoL60Suborder **Valvifera**Family **Idoteidae***Chiridotea coeca* (Say 1818). Jo30; BoL60; FT77; Y77; G78; R79; Wa79*Chiridotea tuftsi* (Stimpson 1853). BoL60; G78*Edotea montosa* (Stimpson 1853). BoL60; G78*Idotea baltica* (Pallas 1772). BoL60; FT77; G78; Pen 78*Idotea phosphorea* Harger 1873. BoL60; FT77; G78; R79; Wa79Suborder **Asellota**Family **Janiridae***Jaera marina* (Fabricius 1780). BoL60; FT77; BBr78; Br78; G78; R79; Wa79Order **Amphipoda**Suborder **Gammaridea**Family **Ampeliscidae***Ampelisca vadorum* Mills 1963. FT77Family **Ampithoidae***Ampithoe rubricata* (Montagu 1808). BoL60; Pen78; R79; Wa79Family **Calliopiidae***Calliopiopus laeviusculus* (Krøyer) 1838. BoL60Family **Corophiidae***Corophium bonelli* (Milne Edwards 1830). BoL60; Y77; G78; R79; Wa79*Corophium crassicorne* Bruzelius 1859. Mc79; Wa79*Corophium tuberculatum* ? Shoemaker 1934. BoL60; G78*Corophium volutator* (Pallas 1766). BoL60; FeR77; FT77; Y77; BBr78; Boa78; Br78; G78; Pen78; R79; Wa79*Unciola irrorata* Say 1818. BoL60; FT77; R79; Wa79Family **Dexaminidae***Dexamine thea* Sars 1893. BoL60Family **Gammaridae***Gammarus annulatus* Smith 1873. AUM*Gammarus lawrencianus* Bousfield 1956. BoL60; FT77; G78; R79; Wa79*Gammarus mucronatus* Say 1818. Jo30; Bai67; N76; BBr78; Br78; G78*Gammarus oceanicus* Segerstrale 1947. BoL60; FT77; G78*Gammarus setosus* Dementieva 1931. BoL60*Gammarus tigrinus* Sexton 1939. BoL60*Marinogammarus finmarchicus* Dahl 1936. BoL60*Marinogammarus obtusatus* Dahl 1936. BoL60*Marinogammarus storerensis* (Reid 1940). BoL60

Melita dentata (Krøyer 1842). BoL60
Rivulogammarus duebeni Lilljeborg 1851. BoL60
Gammarellus angulosus (Rathke 1843). BoL60

Family **Haustoriidae**

Bathyporeia quoddyensis Shoemaker 1949. BoL60; R79; Wa79
Haustorius arenarius Slabber. BoL60

Family **Hyalidae**

Hyale nilssoni (Rathke 1837). BoL60

Family **Ischyroceridae**

Ischyroceros anguipes Krøyer 1838. BoL60
Jassa falcata (Montagu 1808). BoL60

Family **Lysianassidae**

Anonyx sarsi Steele and Brunel 1968. AUM
Hippomedon serratus Holmes 1903. BoL60
Orchomonella minuta (Krøyer 1846). BoL60
Psammonyx nobilis (Stimpson 1853). FT77
Tmetonyx nobilis Stimpson 1853. BoL60

Family **Photidae**

Leptocheirus pinguis (Stimpson 1853). BoL60; R79; Wa79
Leptocheirus plumulosus Shoemaker 1932. Y77
Podoceropsis nitida Stimpson 1853. FT77

Family **Phoxocephalidae**

Harpinia propinqua Sars 1895. R79; Wa79
Phoxocephalus holbolli (Krøyer 1842). BoL60; FT77; R79; Wa79

Family **Pleustidae**

Stenopleustes gracilis (Holmes 1905). BoL60
Sympleustes glaber (Boeck 1861). BoL60

Family **Podoceridae**

Dulichia porrecta (Bate 1857). AUM

Family **Pontogeneiidae**

Pontogeneia inermis (Krøyer 1838). BoL60; R79; Wa79

Family **Talitridae**

Orchestia gammarella (Pallas 1766). BoL60
Orchestia grillus Bosc 1802. BoL60; Bai67; Y77; BBr78; Br78
Orchestia platensis Krøyer 1844. BoL60; Y77
Talorchestia longicornis (Say 1818). BoL60

Order **Caprellida**

Family **Caprellidae**

Aeginina longicornis (Krøyer 1842-3). G78
Caprella linearis (Linnaeus 1767). Pen78
Caprella septentrionalis Krøyer 1838. BoL60

Order **Mysidacea**

Family **Mysidae**

Mysis stenolepis Smith 1873. BoL60; G78
Neomysis americana (Smith 1873). BoL60; FT77; G78

Superorder **Eucarida**

Order **Decapoda**

Infraorder **Caridea**

Family **Hippolytidae**

Eualus gaimardii (Milne-Edwards 1837). Jo30
Eualus pusiolus (Krøyer 1842). BoL60

Family **Crangonidae**

Crangon septemspinosa Say 1818. BoL60; FT77; Y77; G78; R79; Wa79

Infraorder **Astacidea**

Family **Nephropsidae**

Homarus americanus Milne-Edwards 1837. BoL60

Infraorder **Anomura**

Superfamily **Paguroidea**

Family **Paguridae**

Pagurus acadianus Benedict 1901. Jo30; BoL60; FT77; G78; R79; Wa79

Pagurus longicarpus Say 1817. BoL60; Y77; G78

Pagurus pubescens (Krøyer 1838). FT77

Infraorder **Brachyura**

Section **Oxyrhyncha**

Family **Majidae**

Hyas coarctatus Leach 1815. BoL60

Libinia emarginata Leach 1815. BoL60; FT77; Y77

Section **Cancridea**

Family **Cancridae**

Cancer borealis Stimpson 1859. BoL60; FT77; Y77

Cancer irroratus Say 1817. BoL60; FT77; Y77; R79; Wa79

Section **Brachyrhyncha**

Family **Portunidae**

Carcinas maenas (Linnaeus 1758). BoL60; FT77; Y77; BBr78; Br78

Ovalipes ocellatus (Herbst 1799). BoL60; Y77

Class **Insecta**

Subclass **Pterygota**

Order **Diptera**

Family **Tabanidae**

Tabanus nigrovittatus (Macquart). Bai 67

Order **Coleoptera**

Family **Hydrophilidae**

Enochrus hamiltoni Hatch & Kincaid. Bai67

PHYLUM **ECHINODERMATA**

Class **Echinoidea**

Order **Echinoidea**

Family **Strongylocentrotidae**

Strongylocentrotus droebachiensis (Müller 1776). BoL60; FT77

Order **Clypeasteroidea**

Family **Echinarachnidae**

Echinarachnius parma (Lamarck 1816). BoL60

Class **Stelleroidea**

Subclass **Asteroidea**

Order **Spinulosida**

Family **Echinasteridae**

Henricia sanguinolenta (Müller 1776). BoL60; FT77

Order **Forcipulatida**

Family **Asteriidae**

Asterias vulgaris Verrill 1866. BoL60; FT77; R79; Wa79

Family **Asteriidae**

Leptasterias littoralis (Stimpson 1853). BoL60

Subclass **Ophiuroidea**Order **Ophiurida**Family **Ophiactidae***Ophiopholis aculeata* (Linnaeus 1788). FT77Family **Amphiuridae***Amphipholis squamata* (Delle Chiaje 1828). BoL60; R79; Wa79PHYLUM **HEMICHORDATA**Class **Enteropneusta**Family **Harrimaniidae***Saccoglossus kowsalevskii* Agassiz 1873. Y77; R79; Wa79PHYLUM **CHORDATA**Class **Ascidacea**Order **Enterogona**Suborder **Aplousobranchia**Family **Polyclinidae***Amaroucium glabrum* Verrill 1871. BoL60; FT77Family **Didemnidae***Didemnum albidum* (Verrill 1871). FT77Suborder **Phlebobranchia**Family **Ascidiidae***Ascidia callosa* Stimpson 1852. FT77Order **Pleurogona**Suborder **Stolidobranchiata**Family **Pyuridae***Boltenia echinata hirsuta* Agassiz. BoL60*Boltenia ovifera* (Linnaeus 1767). BoL60Family **Molgulidae***Molgula citrina* Alder & Hancock 1848. BoL60; FT77; R79; Wa79Class **Agnatha**Order **Myxiniiformes**Family **Petromyzontidae***Petromyzon marinus* Linnaeus 1758. BMc73Class **Chondrichthyes**Order **Squaliformes**Family **Alopiidae***Alopias vulpinus* (Bonnaterre 1788). BoL60; BMc73; Y77Family **Lamnidae***Carcharodon carcharias* (Linnaeus 1758). BMc73Family **Squalidae***Squalus acanthias* Linnaeus 1758. BoL60; Y77Order **Rajiformes**Family **Rajidae***Raja diaphanes*. BoL60; Y77*Raja erinacea* Mitchill 1825. BoL60; BMc73; Y77*Raja laevis* Mitchill 1817. BoL60; BMc73; Y77*Raja ocellata* Mitchill 1815. BMc73; Y77Class **Osteichthyes**Order **Acipenseriformes**Family **Acipenseridae***Acipenser oxyrhynchus* Mitchill 1815. BoL60; BMc73; Y77; D79

Order **Anguilliformes**

Family **Anguillidae**

Anguilla rostrata (Le Sueur 1817). BoL60; Bai67; BMc73; Y77; Pen78

Order **Clupeiformes**

Family **Clupeidae**

Alosa aestivalis (Mitchill 1815). BoL60; D79

Alosa pseudoharengus (Wilson 1811). BoL60; BMc73; Y77; Pen78; D79

Alosa sapidissima (Wilson 1811). BoL60; BMc73; Y77; Pen78

Brevoortia tyrannus (Latrobe 1802). A69; BMc73; D79

Clupea harengus harengus Linnaeus 1758. BoL60; BMc73; Y77

Order **Salmoniformes**

Family **Salmonidae**

Salmo salar Linnaeus 1758. BoL60; BMc73; Y77

Family **Osmeridae**

Osmerus mordax (Mitchill 1815). BoL60; BMc73; Y77; Pen78

Order **Lophiiformes**

Family **Lophiidae**

Lophius americanus Valenciennes 1873. BoL60; BMc73; Y77

Order **Gadiformes**

Family **Gadidae**

Enchelyopus cimbrius (Linnaeus 1766). BMc73; Y77

Gadus morhua Linnaeus 1758. BoL60; BMc73; Y77; D79

Merluccius bilinearis (Mitchill 1814). BoL60; BMc73; Y77

Microgadus tomcod (Walbaum 1792). BoL60; BMc73; Y77; Pen78; D79

Pollachius virens (Linnaeus 1758). BoL60; Y79

Urophycis chuss (Walbaum 1792). BoL60

Urophycis tenuis (Mitchill 1815). BoL 60; BMc73; Y77; Pen78

Family **Zoarcidae**

Macrozoarces americanus (Bloch & Schneider 1801). BoL60; BMc73; Y77

Order **Atheriniformes**

Family **Cyprinodontidae**

Fundulus diaphanus (LeSueur 1817). D79

Fundulus heteroclitus (Linnaeus 1766). BoL60; Bai67; BMc73; N76; Y77

Family **Atherinidae**

Menidia menidia (Linnaeus 1766). BoL60; BMc73; Y77

Order **Gasterosteiformes**

Family **Gasterosteidae**

Apeltes quadracus (Mitchill 1815). Bai67; D79

Gasterosteus aculeatus Linnaeus 1758. Bai67; N76; Y77; D79

Gasterosteus wheatlandi Putnam 1867. Pen78; D79

Pungitius pungitius (Linnaeus 1758). Bai67; D79

Family **Syngnathidae**

Syngnathus fuscus Storer 1839. BoL60; BMc73; Y77

Order **Perciformes**

Family **Percichthyidae**

Morone saxatilis (Walbaum 1792). BoL60; BMc73; Y77

Family **Sciaenidae**

Cynoscion regalis (Bloch & Schneider 1801). D79

Family **Pholidae**

Pholis gunnellus (Linnaeus 1758). BoL60; BMc73; Y77

Family **Anarchichadidae***Anarchichas lupus* Linnaeus 1758. Y77Family **Ammodytidae***Ammodytes americanus* DeKay 1842. BoL60; Y77*Ammodytes dubius* Reinhardt 1838. BMc73Family **Scombridae***Scomber scombrus* Linnaeus 1758. BoL60; Y77Family **Stromateidae***Poronotus triacanthus* (Peck 1800). BoL60; BMc73; Y77Family **Cottidae***Hemitripterus americanus* (Gmelin 1789). BoL60; BMc73; Y77; D79*Myoxocephalus aeneus* (Mitchill 1815). BoL60; BMc73; Y77*Myoxocephalus octodecemspinosus* (Mitchill 1815). BoL60; Y77*Myoxocephalus scorpius* (Linnaeus 1758). BMc73; Y77Family **Cyclopteridae***Cyclopterus lumpus* Linnaeus 1758. BoL60; BMc73; Y77*Liparis atlanticus* (Jordan & Evermann 1898). BMc73; D79*Liparis coheni* (Able 1973). D79Order **Pleuronectiformes**Family **Bothidae***Scophthalmus aquosus* (Mitchill 1815). BoL60; BMc73; Y77; D79Family **Pleuronectidae***Liopsetta putnami* (Gill 1864). BoL60; BMc73; Y77; Pen78*Pseudopleuronectes americanus* (Walbaum 1792). BoL60; BMc73; Y77; Pen78**Bibliography**

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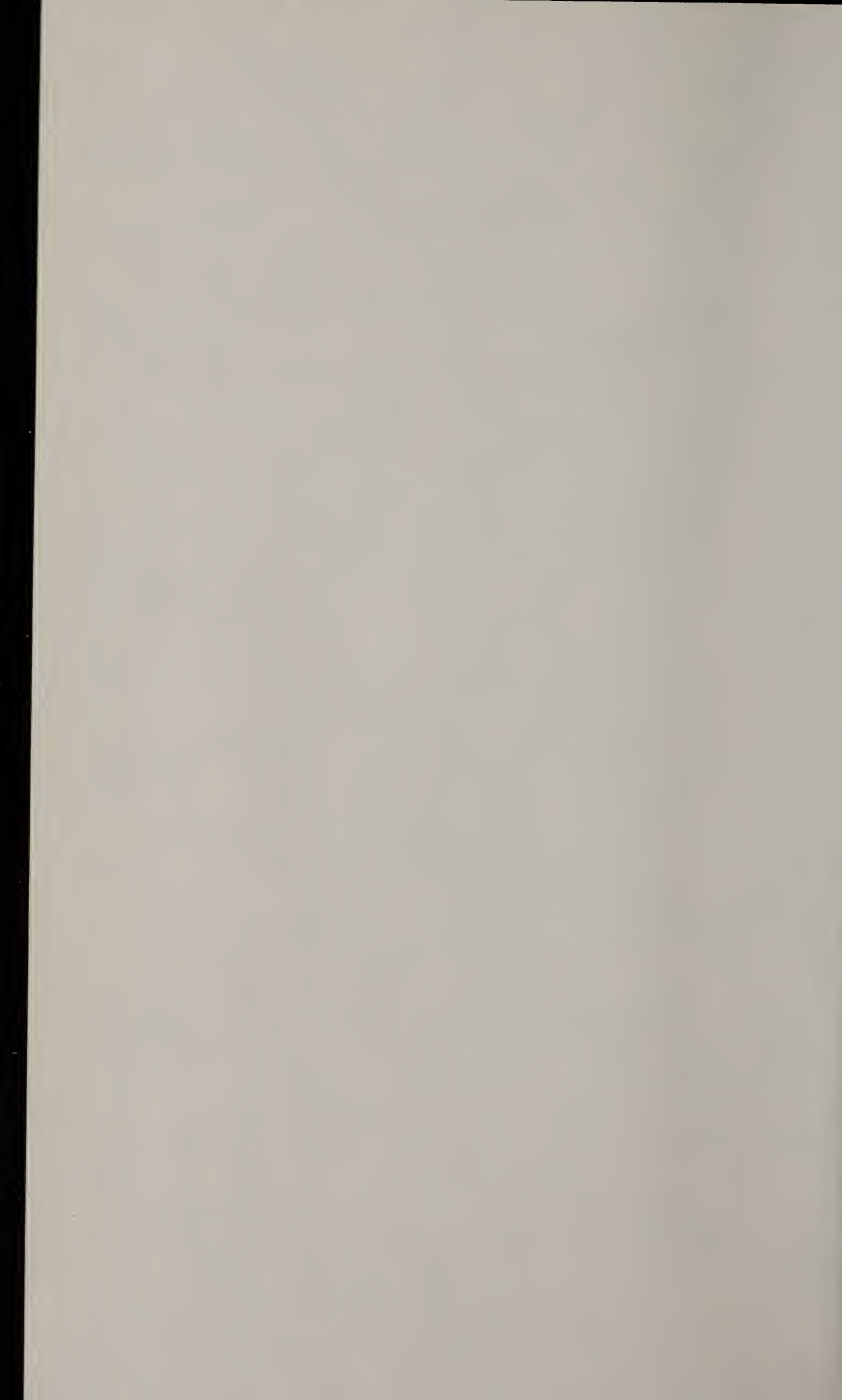
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